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METHODS FOR ASSESSING EXPOSURE TO CHEMICAL SUBSTANCES

Volume 3

Methods for Assessing Exposure from Disposal of Chemical Substances

by

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EPA Contract No. 68-01-6271

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U.S. ENVIRONMENTAL PROTECTION AGENCY
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FOREWORD

This document is one of a series of volumes, developed for the U.S. Environmental Protection Agency (EPA), Office of Toxic Substances (OTS), that provides methods and information useful for assessing exposure to chemical substances. The methods described in these volumes have been identified by EPA-OTS as having utility in exposure assessments on existing and new chemicals in the OTS program. These methods are not necessarily the only methods used by OTS, because the state-of-the-art in exposure assessment is changing rapidly, as is the availability of methods and tools. There is no single correct approach to performing an exposure assessment, and the methods in these volumes are accordingly discussed only as options to be considered, rather than as rigid procedures.

Perhaps more important than the optional methods presented in these volumes is the general information catalogued. These documents contain a great deal of non-chemical-specific data which can be used for many types of exposure assessments. This information is presented along with the methods in individual volumes and appendices. As a set, these volumes should be thought of as a catalog of information useful in exposure assessment, and not as a "how-to" cookbook on the subject.

The definition, background, and discussion of planning exposure assessments are discussed in the introductory volume of the series (Volume 1). Each subsequent volume addresses only one general exposure setting. Consult Volume 1 for guidance on the proper use and interrelations of the various volumes and on the planning and integration of an entire assessment.

The titles of the nine basic volumes are as follows:

Volume 1	Methods for Assessing Exposure to Chemical Substances (EPA 560/5-85-001)
Volume 2	Methods for Assessing Exposure to Chemical Substances in the Ambient Environment (EPA 560/5-85-002)
Volume 3	Methods for Assessing Exposure from Disposal of Chemical Substances (EPA 560/5-85-003)
Volume 4	Methods for Enumerating and Characterizing Populations Exposed to Chemical Substances (EPA 560/5-85-004)
Volume 5	Methods for Assessing Exposure to Chemical Substances in Drinking Water (EPA 560/5-85-005)

Volume 6	Methods for Assessing Occupational Exposure to Chemical Substances (EPA 560/5-85-006)
Volume 7	Methods for Assessing Consumer Exposure to Chemical Substances (EPA 560/5-85-007)
Volume 8	Methods for Assessing Environmental Pathways of Food Contamination (EPA 560/5-85-008)
Volume 9	Methods for Assessing Exposure to Chemical Substances Resulting from Transportation-Related Spills (EPA 560/5-85-009)

Because exposure assessment is a rapidly developing field, its methods and analytical tools are quite dynamic. EPA-OTS intends to issue periodic supplements for Volumes 2 through 9 to describe significant improvements and updates for the existing information, as well as adding short monographs to the series on specific areas of interest. The first four of these monographs are as follows:

Volume 10	Methods for Estimating Uncertainties in Exposure Assessments (EPA 560/5-85-014)
Volume 11	Methods for Estimating the Migration of Chemical Substances from Solid Matrices (EPA 560/5-85-015)
Volume 12	Methods for Estimating the Concentration of Chemical Substances in Indoor Air (EPA 560/5-85-016)
Volume 13	Methods for Estimating Retention of Liquids on Hands (EPA 560/5-85-017)

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1. INTRODUCTION

This report presents methods and supporting information for estimating environmental releases from the disposal of wastes. Companion volumes provide procedures for assessing the following other exposure scenarios: the ambient environment (Volume 2), drinking water (Volume 5), the occupational environment (Volume 6), consumer products (Volume 7), food (Volume 8), and transportation-related spills (Volume 9). An introduction to the entire methods development series is in Volume 1 and recommended methods for enumerating and characterizing populations are presented in Volume 4. The purpose, scope, and limitations of this volume are discussed below, followed by an overview of the problem of exposures to chemical substances from disposal. The methodological framework is presented in Section 2, and applications of the methods to selected waste disposal practices are presented in Sections 3 through 8.

1.1 Purpose and Scope

This document provides procedures for estimating environmental releases from waste disposal activities used in exposure assessments performed by the U.S. Environmental Protection Agency (EPA) Office of Toxic Substances (OTS) under the mandate of the Toxic Substances Control Act (TSCA). The present volume must be used together with Volumes 2, 5, and 7, which deal with the ambient, drinking water, and consumer exposure scenarios, respectively. Volumes 2 and 7 are used to develop information on quantities and characteristics of the subject waste. Starting with this information, the present volume guides the assessor through the assumptions, calculations, and estimations that are required to characterize and quantify releases to air, land, and water. The assessor must then return to Volumes 2 and 5 to relate these releases to ultimate exposure, thereby completing the assessment. See Volume 1 for a discussion of the nature and purpose of exposure assessments in general as well as for a more detailed explanation of the interrelations and integration of the various volumes.

A separate volume was created for the disposal setting because of the need to develop a detailed information base for what is assumed to be a major source of environmental releases of toxic substances. This volume fills a need in the discipline of exposure assessment because there exists no comprehensive information source covering the range of topics and data sources that must be considered in estimating chemical releases from waste disposal.

Methods are developed to the greatest extent possible for six waste treatment/disposal practices that have a great potential for environmental contamination either because they handle relatively large quantities of waste or because they have been known to release significant quantities of toxic substances to the environment. These practices are: landfilling, land treatment, surface impoundment, municipal wastewater treatment, incineration, and deep-well injection. Methods for estimating environmental releases resulting from storage of wastes prior to disposal are not provided except in the case of storage in surface impoundments. Similarly, with the exception of wastewater treatment and incineration, waste handling methods that are purely treatment (as opposed to ultimate disposal) techniques were not included in the volume. (Treatment consists of any process designed to change the physical, chemical, or biological character or composition of a waste for the purpose of making it safer for transport, amenable to recovery or storage, or reduced in volume. Examples include neutralizing a strong acid, degrading a chemical compound, or sterilizing infectious waste.)

It should be emphasized that the scope of this report is limited to methods leading to estimation of environmental releases from disposal sites and that the companion volumes must be consulted in order to complete the exposure assessment. See Volume 1 of this series for guidance on this.

1.2 Limitations

This methodology represents the synthesis of a large body of information from a variety of sources. The five-stage framework approach should be applicable to any waste treatment or disposal method. The information base represented in both the site-specific and the generic data presented in this report is likely to expand in the next few years. For the present, however, there are significant data and model gaps that can be filled only by making assumptions and/or using predictive techniques that are largely untested. Some of these assumptions can be evaluated with respect to their uncertainty using a sensitivity analysis, but other data and model gaps cannot presently be compensated for. For instance, the effect of other constituents in a waste matrix on the chemical of interest is very chemical-specific and little understood. A related issue is the problem of determining which new, potentially toxic compounds may be formed during treatment or disposal of the subject chemical and how fast they will be released from the waste matrix. This can be answered only through further research. In the meantime, the user will have to decide whether collecting detailed data in several stages of the methodology is worthwhile if other stages cannot be accurately quantified.

1.3 Overview - Potential for Exposure to Chemical Substances from Waste Disposal

The number of steps in the waste handling process varies considerably, depending on the nature and source of the waste and available waste handling methods. The disposal process for a consumer product discarded in residential waste that is taken to a landfill is quite simple. However, the fate of the chemical constituents in that consumer product may be complex, and some of a given chemical may end up in the air, some on land, some in groundwater, and some in surface waters. The picture is even more complex for the chemical constituents of a consumer product washed down a drain and routed to a sewage treatment plant. Depending on the sewage treatment methods, portions of the chemical may be discharged in the effluent and may end up in the air, surface water, groundwater, or land. Another portion of the chemical may be concentrated in the wastewater treatment sludge, which may also be treated and disposed of in ways that result in releases to air, land, surface water, and groundwater. An overview of waste disposal patterns and the interrelationship between the six waste treatment/disposal practices examined in this volume is presented in Table 1 and graphically in Figure 1.

Table 1. Overview of Six Waste Treatment/Disposal Methods

Waste treatment/ disposal method	Type of wastes handled	Residues	Possible environmental emissions
Landfills[f]	Industrial solid waste[a], MSW[b], incinerator residues, POTW sludge[e]	None[c]	Air, surface water, land, groundwater
Land treatment[g]	POTW wastewaters and sludge,[e] industrial solid waste[a]	None[c]	Air, surface water, land groundwater
Surface impoundment[h]	Wastewaters, industrial solid waste[a], incinerator residues	None[c]	Air, surface water, land, groundwater
POTWs[e]	Municipal and industrial wastewater	Wastewater treatment sludge (ultimately disposed of by landfilling, land treatment incineration, or surface impoundment)	Air, surface water, land, groundwater
Incinerators[i]	Industrial solid waste[a], POTW sludge, and MSW[b]	Ash (disposed of in landfills or surface impoundments); wastewater	Air, surface water, land, groundwater
Injection wells[j]	Wastewater, industrial solid waste[a]	None	Groundwater

[a] Includes both hazardous and nonhazardous wastes; may be in liquid form.

[b] Municipal solid waste.

[c] Leachate is sometimes collected and treated.

[d] Surface impoundments may be used to treat or store wastes that are ultimately disposed of by landfilling.

[e] Publicly Owned Treatment Works (municipal sewage treatment plant). Surface impoundment and land treatment may be included in the treatment process.

[f] A method of waste disposal whereby wastes are placed on the ground and covered with soil.

[g] A disposal technique by which wastes are mixed with the surface soil and allowed to be degraded through natural processes.

[h] A waste handling technique whereby liquid wastes are treated, stored, or disposed of in a natural or manmade topographical depression.

[i] A waste treatment method that involves the controlled burning of wastes resulting in thermal destruction.

[j] A waste disposal method that involves injecting liquid wastes into a permeable rock layer below the surface.

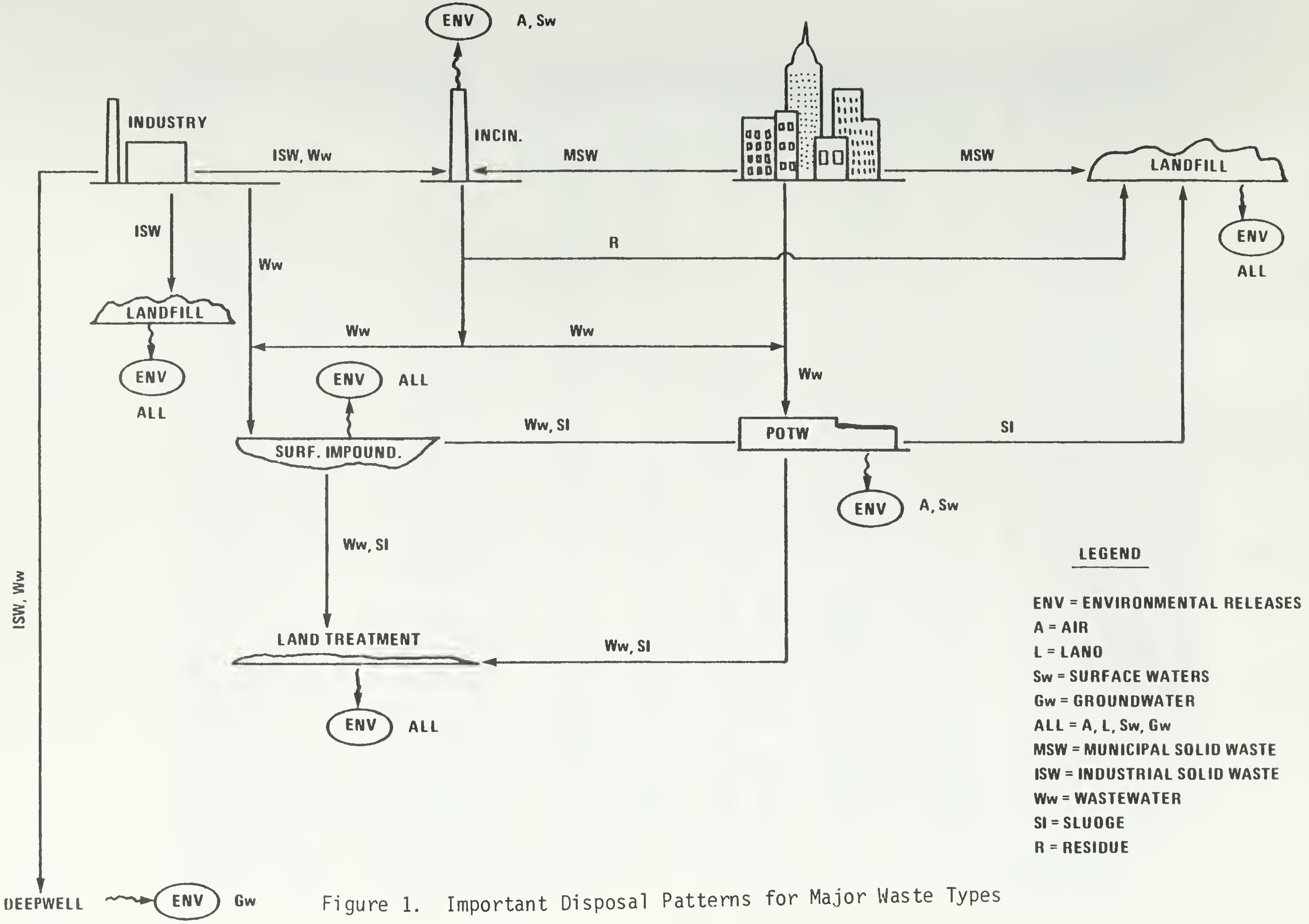


Figure 1. Important Disposal Patterns for Major Waste Types

2. GENERAL METHODOLOGICAL APPROACH

The methods development series is designed to fulfill the wide-ranging needs associated with assessing exposure from chemical substances. Although tailored specifically for use in exposure assessments required under TSCA, the approach should be applicable to all types of exposure assessments that include the disposal scenario. In order to provide a useful tool for current and future studies, the method has to be:

- Comprehensive, in that all possible waste types and disposal methods can be evaluated using a consistent procedure.

- Flexible, so that it can be used for all kinds of assessments, ranging from detailed site-specific studies to large-scale nationwide assessments, and can be easily modified as new sources of information become available.

- Reliant on readily available sources of data.

- Amenable to the input of site- and chemical-specific data, as well as to generic data, algorithms, and models.

- Applicable to assessing exposure from waste-handling practices that include one or more steps (e.g., treatment prior to disposal).

Based on these criteria, a five-stage framework was developed for the present volume which leads the user from source information compiled from a materials balance and the results of preliminary ambient and consumer exposure assessments to the final estimation of environmental releases from disposal sites. For each stage in the framework, a general procedure was developed for estimating the output of that stage. These procedures will be referred to as "decision trees." These general decision trees were then tailored to those waste categories and disposal methods considered to be the most significant sources of exposure to chemical substances.

Section 2.1 provides an overview of how this volume fits into a complete exposure assessment. The five-stage framework is presented in Section 2.2, and the general decision trees applicable to each of the five stages are presented in Section 2.3. Finally, the applications of this approach to the six disposal/treatment categories selected for investigation (landfills, land treatment, surface impoundments, sewage treatment plants, incinerators, and injection wells) are developed in Sections 3 through 8.

The procedures suggested in this volume are based on a review of available literature and data bases, and contacts with EPA and state solid waste agency personnel. A resource matrix summarizing important information sources is given in Appendix A. Appendices B through J contain summaries or sample data from information resources that may be useful in implementing the suggested procedures. A list of useful conversion factors is presented as Appendix K.

2.1 Integration with Other Exposure Scenarios

It cannot be overemphasized that this volume does not constitute a self-contained exposure assessment method, but falls entirely within the scope of the source analysis required for an ambient (or drinking water) exposure assessment. This is true even when only disposal-related exposure is being assessed. The input to the disposal analysis is quantitative and qualitative information on the subject waste that must be provided, at least in part, by procedures discussed in the companion volumes on the ambient and consumer settings (Volumes 2 and 7, respectively). The ultimate output of the disposal analysis consists of quantitative estimates of releases, substance concentrations, and release characteristics for the relevant disposal methods. This information does not by itself constitute the desired output of a complete exposure assessment; it is mere raw data which must be input to an ambient (and/or drinking water) analysis. It is these latter analyses which will determine the subject chemical's fate and the ultimate environmental concentrations to which receptors may be exposed. A separate population analysis must also be conducted (see Volume 4). Consult the introductory volume to this series (Volume 1) for a more detailed discussion of how the individual volumes are used together to perform an integrated assessment.

This volume is designed to be useful for assessments of any scope and depth, as explained in the following subsection. The desired scope and depth of the assessment should be determined before the actual analysis is begun. However, the original scope and depth may have to be modified in the course of the assessment in response to unexpected data limitations or other factors. See Volume 1 of this series for guidance on these and similar planning issues.

2.2 Framework for Estimating Releases

A five-stage framework for estimating chemical releases to air, surface waters, groundwater, and land from disposal is presented as Figure 2. The framework forms the foundation of this method by outlining the major steps that must be taken to estimate releases from disposal sites regardless of the disposal practice. The input to the

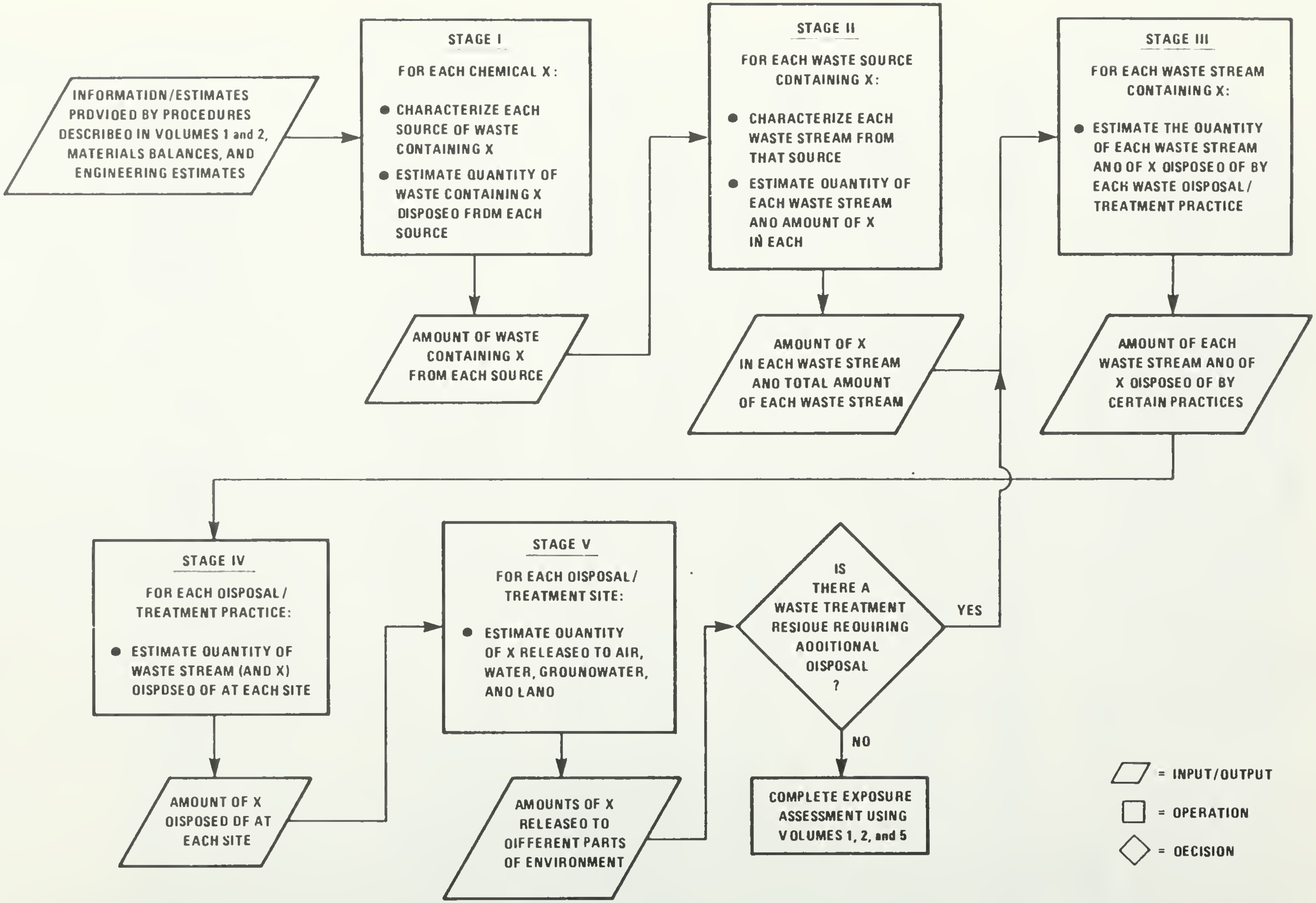

INFORMATION/ESTIMATES PROVIDED BY PROCEDURES DESCRIBED IN VOLUMES 1 and 2, MATERIALS BALANCES, AND ENGINEERING ESTIMATES
STAGE I
FOR EACH CHEMICAL X:
● CHARACTERIZE EACH SOURCE OF WASTE CONTAINING X
● ESTIMATE QUANTITY OF WASTE CONTAINING X DISPOSED FROM EACH SOURCE
AMOUNT OF WASTE CONTAINING X FROM EACH SOURCE
STAGE II
FOR EACH WASTE SOURCE CONTAINING X:
● CHARACTERIZE EACH WASTE STREAM FROM THAT SOURCE
● ESTIMATE QUANTITY OF EACH WASTE STREAM AND AMOUNT OF X IN EACH
AMOUNT OF X IN EACH WASTE STREAM AND TOTAL AMOUNT OF EACH WASTE STREAM
STAGE III
FOR EACH WASTE STREAM CONTAINING X:
● ESTIMATE THE QUANTITY OF EACH WASTE STREAM AND OF X DISPOSED OF BY EACH WASTE DISPOSAL/ TREATMENT PRACTICE
AMOUNT OF EACH WASTE STREAM AND OF X DISPOSED OF BY CERTAIN PRACTICES
STAGE IV
FOR EACH DISPOSAL/ TREATMENT PRACTICE:
● ESTIMATE QUANTITY OF WASTE STREAM (AND X) DISPOSED OF AT EACH SITE
AMOUNT OF X DISPOSED OF AT EACH SITE
STAGE V
FOR EACH DISPOSAL/ TREATMENT SITE:
● ESTIMATE QUANTITY OF X RELEASED TO AIR, WATER, GROUNDWATER, AND LAND
AMOUNTS OF X RELEASED TO DIFFERENT PARTS OF ENVIRONMENT
IS THERE A WASTE TREATMENT RESIDUE REQUIRING ADDITIONAL DISPOSAL ?
YES
NO
COMPLETE EXPOSURE ASSESSMENT USING VOLUMES 1, 2, and 5
= INPUT/OUTPUT
= OPERATION
= DECISION

FIGURE 2. OVERVIEW OF FIVE-STAGE FRAMEWORK FOR ESTIMATING ENVIRONMENTAL RELEASES FROM DISPOSAL

framework is information on the waste that will be partially provided by the ambient and consumer exposure scenarios and a materials balance. Two types of output result from the initial use of the framework. The first consists (at least ideally) of quantitative estimates of releases, chemical concentrations, and release characteristics for ultimate disposal methods, as discussed previously. The other output consists of quantitative information on secondary treatment residues that result from waste treatment practices. The latter may serve as input for another iteration of the framework to quantify releases from ultimate disposal of the residues. Total estimated releases from all treatment and disposal of the subject waste are used as input to an ambient and/or drinking water analysis to complete the assessment (see Volume 1).

The framework is organized as follows: Stage I involves determining the total mass of the chemical that is disposed of from a given source. The source may be one or more industrial plants, commercial users, or consumer users.

Stage II entails estimating the mass and concentration of the chemical in each waste stream, along with the characteristics of the waste matrix in which it is incorporated (e.g., municipal solid waste, sludge). One source may produce several waste streams containing a given chemical; for example, a consumer may flush a cleaning agent down a drain and later discard its container in the household garbage.

Stage III estimates the proportion of each subject waste stream that is disposed of by each available disposal method. If the source of the waste stream is a single manufacturing plant, then 100 percent of the waste stream may be disposed of by one method. If more than one source contributes to the waste stream, or if the waste stream results from consumer use, then more than one disposal method will probably be involved.

Stage IV is the quantitative estimation of how the subset of waste handled by each disposal method is distributed among individual disposal sites. For example, Stage III may estimate that 80 percent of a given waste stream is landfilled; Stage IV then estimates how much of the landfilled portion of the waste stream is taken to each specific landfill location. This stage can be omitted in assessments that do not require site-specific data, as determined before beginning the assessment (see Volume 1). The user should read the applicable decision tree for Stage IV in any case, since it may provide options or alternatives depending on the degree of site-specificity desired.

Stage V estimates environmental releases of the subject chemical from the disposal sites enumerated in Stage IV. For assessments that are not site-specific, releases can be estimated for a statistically representative sample of disposal sites or from one hypothetical site that is designed to be representative of all sites. The Stage V decision trees are designed to be useful for any of these alternatives; a general discussion of the different approaches is presented briefly in Volume 1 of this series.

The user should note that the framework need not be followed in sequence from Stage I to Stage V for all wastes. For example, if information has already been compiled on the quantity of waste handled by each disposal method for a particular substance (the equivalent to the output of Stage III), the assessor can start at Stage IV of the procedure. Wastes that are products of waste treatment (such as incinerator residues) are characterized in Stage V of the treatment analysis. These characteristics (mass of chemical, concentration of chemical, and mass or volume of waste matrix or treatment residue) are used as input to Stage III in order to complete that estimation of environmental releases. In the case of wastewater, a number of very different treatment/disposal methods may be used sequentially on-site (e.g., surface impoundments, tanks, land treatment). Thus, the framework from Stage III through Stage V may be repeated several times to estimate total environmental releases from sewage treatment plants (POTWs).

The types of data required by the framework depend on the particular stage and the waste type and disposal method of interest. Data types include: (1) site-specific or chemical-specific data from a data base, federal or state agency files, or a document; (2) general data compiled from data bases or documents; (3) algorithms; and (4) models. In any given step of a stage, the user may be limited to one of the above because of availability, or may be presented with a choice based on the scope, depth, and approach of the assessment (see Volume 1).

2.3 General Decision Trees for Stages I Through V

This section contains the general decision trees that were developed for each of the five stages of the disposal framework. They outline the factors that should be routinely considered when this method is used. They are the basis for the detailed decision trees presented in Sections 3 through 8, which are individually tailored to each disposal practice. Future expansions of this method to include waste disposal/treatment practices not examined in this report will be facilitated if the general decision trees are used as guidance. Not every step in the decision trees will apply to all wastes or disposal practices. The wide variety of method applications and information sources make a single "cook book" approach to estimating environmental releases from disposal impractical. Successful use of the methods recommended in this report, therefore, depends on an understanding of the following factors: (1) the relationship of each step to the desired output; (2) the relationship between the various steps and stages; and (3) an acquaintance with useful information resources. Graphical summaries of the major steps and key outputs are provided for each stage in the five-stage framework to orient the inexperienced user. These figures, as well as Figure 2 presented previously, should be consulted as often as necessary to maintain perspective when applying the procedures outlined in this report to practical exposure assessment problems.

The data required as input for each stage generally consist of the output of the previous stage, with the exception of residual wastes that are produced by waste treatment (as opposed to disposal) methods. In that case, the output of Stage V for the treatment process will become the input of Stage III of the disposal process.

The user should keep track of the quantitative uncertainty associated with each step or estimate. Because of the limited nature of many of the data, the estimate of uncertainty will be coarse and will be expressed as an order of magnitude or a range of observed values. Obviously, the user should perform a statistically based analysis of uncertainty if the data warrant such an approach.

Stages I and II of the framework are based entirely on outputs from the ambient and consumer exposure analyses (Volumes 2 and 7) and a materials balance and are estimated only once (and in direct sequence) for a given source of waste. Stage III is performed once for each waste stream enumerated in Stage II. Stages IV and V are conducted once (and in direct sequence) for each disposal practice applicable to the waste stream. (See Figure 2.)

2.3.1 Stage I Decision Tree - Estimating Releases to Disposal

A flow chart summarizing the steps in Stages I and II is presented in Figure 3. The input for this stage is derived from a materials balance and the results of preliminary ambient and consumer exposure assessments. Methods for analyzing the ambient and consumer settings are presented in Volumes 2 and 7 of this series; a materials balance will generally have been prepared prior to, or as part of, these analyses. The typical materials balance may not provide sufficient resolution for Stage I of a very detailed disposal analysis; in this case, engineering expertise may be required to help predict waste characteristics and quantities.

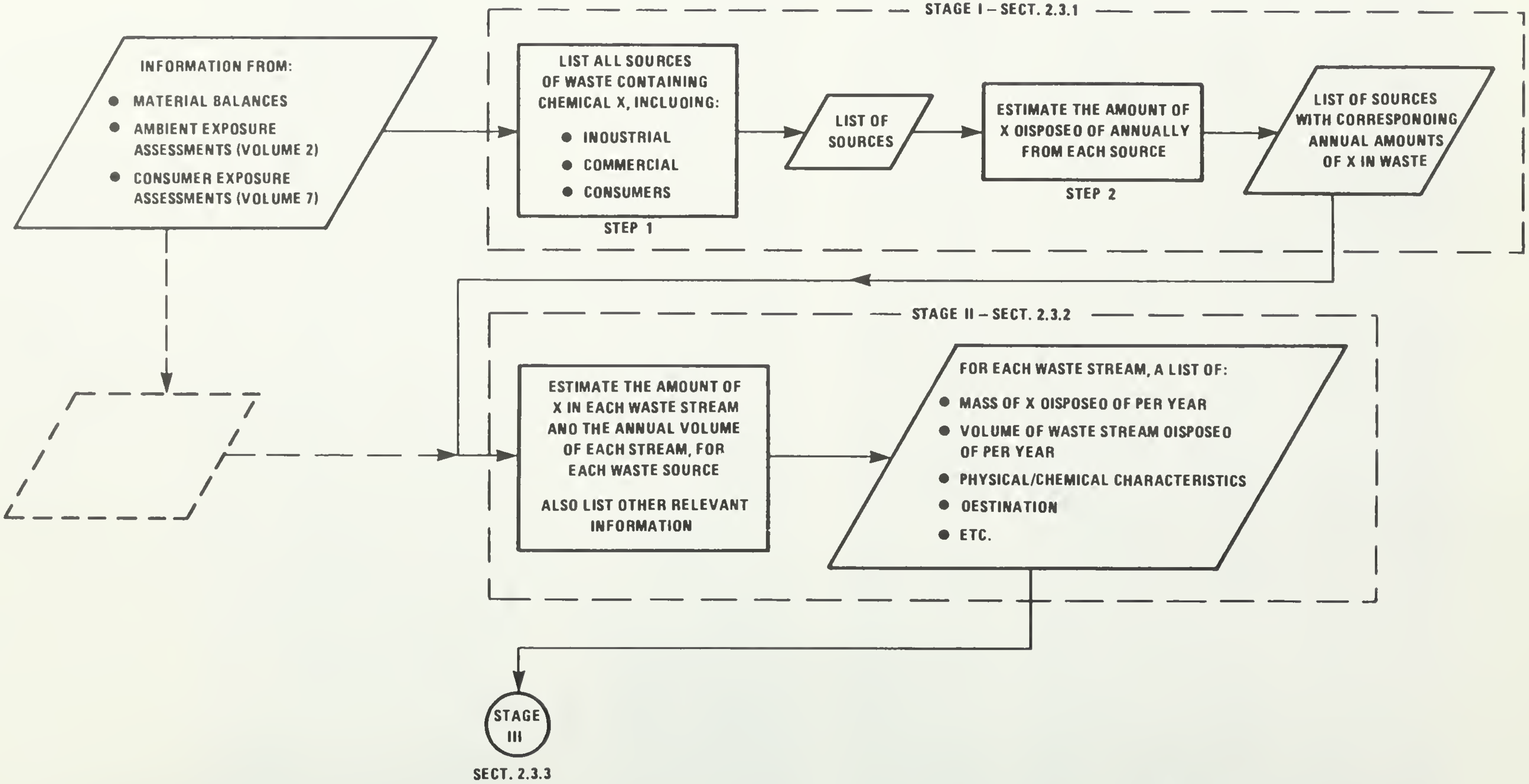

INFORMATION FROM:
● MATERIAL BALANCES
● AMBIENT EXPOSURE ASSESSMENTS (VOLUME 2)
● CONSUMER EXPOSURE ASSESSMENTS (VOLUME 7)
STAGE I – SECT. 2.3.1
LIST ALL SOURCES OF WASTE CONTAINING CHEMICAL X, INCLUDING:
● INDUSTRIAL
● COMMERCIAL
● CONSUMERS
STEP 1
LIST OF SOURCES
ESTIMATE THE AMOUNT OF X DISPOSED OF ANNUALLY FROM EACH SOURCE
STEP 2
LIST OF SOURCES WITH CORRESPONDING ANNUAL AMOUNTS OF X IN WASTE
STAGE II – SECT. 2.3.2
ESTIMATE THE AMOUNT OF X IN EACH WASTE STREAM AND THE ANNUAL VOLUME OF EACH STREAM, FOR EACH WASTE SOURCE
ALSO LIST OTHER RELEVANT INFORMATION
FOR EACH WASTE STREAM, A LIST OF:
● MASS OF X DISPOSED OF PER YEAR
● VOLUME OF WASTE STREAM DISPOSED OF PER YEAR
● PHYSICAL/CHEMICAL CHARACTERISTICS
● DESTINATION
● ETC.
STAGE III
SECT. 2.3.3

Figure 3. Stage I and II Flow Chart

Step 1. List all likely sources of waste containing the subject chemical, including:

a. Industries involved in primary and secondary production.
b. Commercial users.
c. Consumer users.

Data for 1.a may be derived from a materials balance and the results of a preliminary ambient exposure assessment (Volume 2). For 1.b and 1.c, first enumerate the end products containing the chemical, and then determine the potential for use in the commercial/consumer sector. Relevant information may be obtained from the results of a preliminary consumer exposure assessment (Volume 7), and, in the case of 1.b, a materials balance.

Step 2. For each source/use listed in Step 1, estimate the amount of the subject chemical disposed of annually, again based on a materials balance and information collected for the ambient and consumer exposure analyses.

The output of Stage I should be a list of sources/uses of waste containing the subject chemical and estimates of the quantities of the chemical ultimately disposed of from each source/use.

2.3.2 Stage II Decision Tree - Characterizing Waste Stream Releases and Concentrations

A flow chart summarizing the steps in Stage II was presented in Figure 3. The goal of this stage is to characterize the individual waste streams that are included in the total waste quantities estimated in Stage I. This must be done both quantitatively and qualitatively. The input for this stage will be derived from the same sources as the Stage I information; in fact, it may already have been compiled in order to estimate the Stage I output. As in Stage I, engineering expertise may be required.

Step 1. For each source/use of the subject chemical listed in Stage I, determine whether the resulting waste is likely to be separated into different waste streams prior to disposal. If different waste streams are combined prior to disposal, only the combined waste stream need be considered. For each combined waste stream, estimate the total annual quantity of the chemical disposed of (kkg/year) and the total volume or mass of the waste stream containing the chemical. In addition, list other known physical/chemical characteristics of the waste matrix that are relevant to disposal, including other chemicals and minerals present (and their concentrations) and the physical state (e.g., liquid, solid, sludge). This will provide a profile of each waste stream that will be useful for Stage III determination of likely disposal methods and Stage V estimates of releases.

Consider the following:

- For industrial wastes, this determination will be based largely on a materials balance and engineering judgment.

- For the commercial use sector, the distribution of discarded consumer products among various waste streams will depend largely on the waste handling practices in use, which are limited. For many commercial establishments, the wastes will be aggregated into one of two waste streams: sewage (i.e., wastewater) and solid waste. In addition, solid waste may sometimes be separated into more than one category based on size and nature of wastes. In the absence of specific information, however, assume that commercial products are discarded in the same waste streams as are consumer use products.

- For the consumer use sector, it can generally be assumed that waste will be discarded in either of two waste streams: wastewater or municipal solid waste. Their relative amounts may be determined from information on the use of the applicable consumer product(s) compiled for the consumer exposure scenario (Volume 7).

Quantitative information on the lifetime of consumer products and how much of the chemical substance is contained in products at the time of disposal may have been compiled for the consumer portion of the exposure assessment. Otherwise, Consumer Product Safety Commission (CPSC) publications such as Lahr and Gordon (1980) may be helpful. The output of Stage II should include the following for each waste stream from each source of waste containing the subject chemical:

- Name or description of waste stream
- Annual loading of subject chemical (mass/year)
- Volume of mass of waste matrix containing subject chemical (quantity/year)
- Destination of waste stream (i.e., land or sewers)
- Relevant chemical/physical properties of waste stream
- Information on the source of waste stream, including location and SIC Code, if relevant (from Stage I).

2.3.3 Stage III Decision Tree - Allocating Waste Streams to Disposal Practices

The steps in this decision tree are summarized in Figure 4. This stage in the disposal framework determines the disposal/treatment practices likely to be employed for a given waste stream and estimates the amounts of waste disposed of by each of the identified practices.

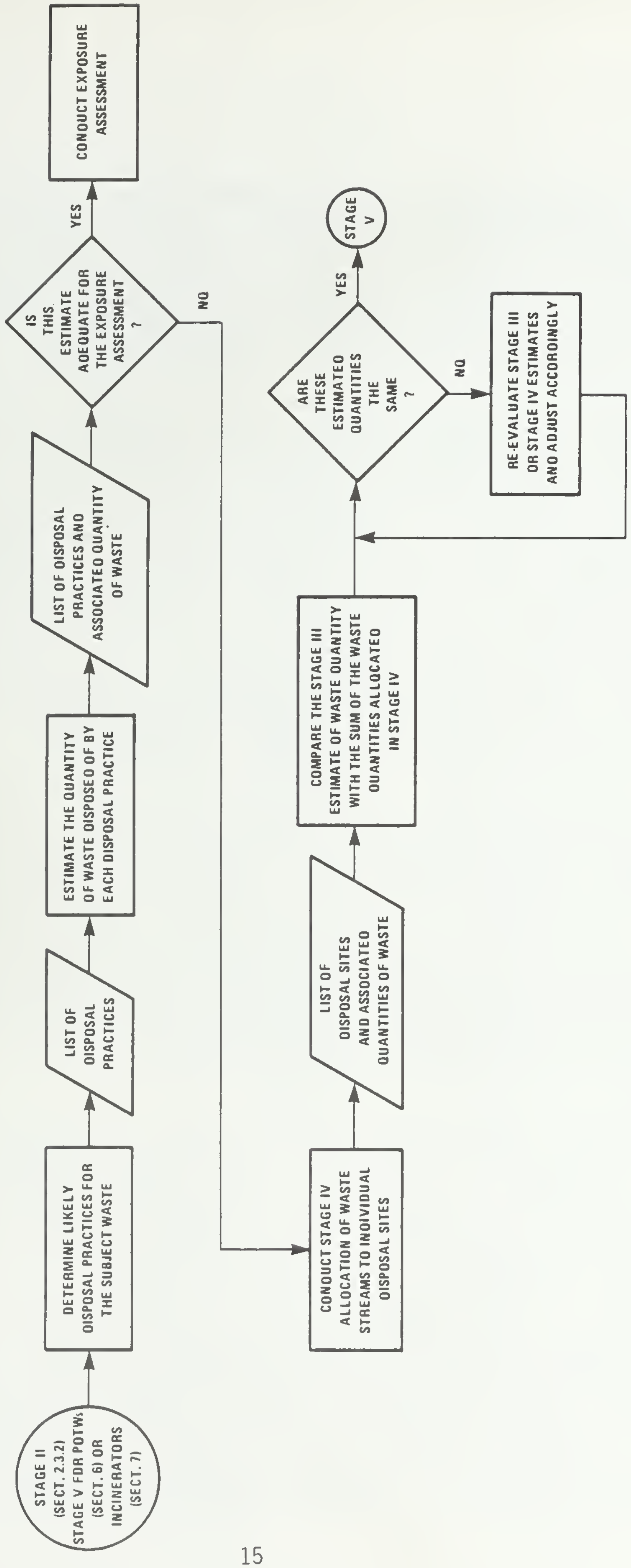

STAGE II (SECT. 2.3.2) STAGE V FOR POTWs (SECT. 6) OR INCINERATORS (SECT. 7)
DETERMINE LIKELY DISPOSAL PRACTICES FOR THE SUBJECT WASTE
LIST OF DISPOSAL PRACTICES
ESTIMATE THE QUANTITY OF WASTE DISPOSED OF BY EACH DISPOSAL PRACTICE
LIST OF DISPOSAL PRACTICES AND ASSOCIATED QUANTITY OF WASTE
IS THIS ESTIMATE ADEQUATE FOR THE EXPOSURE ASSESSMENT ?
YES
CONDUCT EXPOSURE ASSESSMENT
NO
CONDUCT STAGE IV ALLOCATION OF WASTE STREAMS TO INDIVIDUAL DISPOSAL SITES
LIST OF DISPOSAL SITES AND ASSOCIATED QUANTITIES OF WASTE
COMPARE THE STAGE III ESTIMATE OF WASTE QUANTITY WITH THE SUM OF THE WASTE QUANTITIES ALLOCATED IN STAGE IV
ARE THESE ESTIMATED QUANTITIES THE SAME ?
YES
STAGE V
NO
RE-EVALUATE STAGE III OR STAGE IV ESTIMATES AND ADJUST ACCORDINGLY

FIGURE 4. SUMMARY OF STAGE III: ALLOCATING WASTE STREAMS TO DISPOSAL METHODS

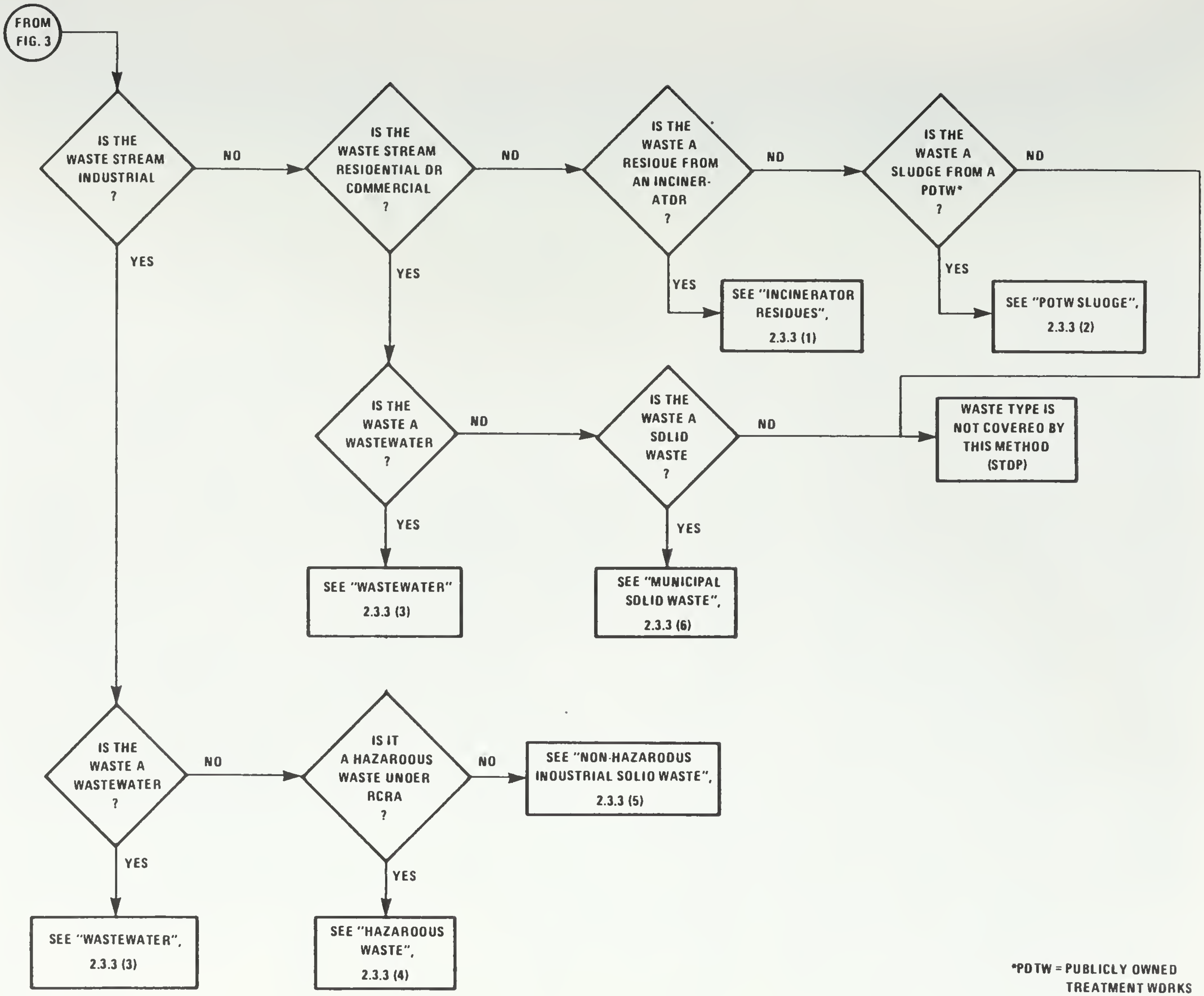
The input to Stage III for a given waste stream is information on the source, waste generation rate (volume or mass per time), chemical concentration, and physical state of the waste stream. Using this information and the decision trees provided in this section, the user estimates the quantity of subject waste destined for each likely disposal practice. The output of Stage III serves both as a starting point and as a check point for the site-specific Stage IV estimates.

One feature of this approach is that it allows various levels of refinement, depending on the needs and resources of a given exposure assessment. An example is the method for arriving at Stage III estimates. The preliminary Stage III estimates can be based on readily available precompiled information on regional or national disposal practices. For exposure assessments that treat the disposal scenario superficially, these "gross" estimates may be the end point of the investigation. In cases where a more refined estimate is desirable, however, the user can take advantage of available site-specific data suggested in the Stage IV methods, and use this information to re-evaluate the original Stage III estimates. Thus, the Stage III and Stage IV estimates will often be iterative and should be compared carefully in order to produce compatible estimates of waste quantities for all general practices and specific disposal sites.

The procedure for determining the disposal practice likely to handle a given waste stream is organized by waste category. Six general waste categories were selected to be addressed in this report. These are: incinerator residues, POTW sludge, wastewater, hazardous waste, industrial nonhazardous solid waste, and municipal solid waste. Virtually all wastes of interest in exposure assessments will probably fit into one of these categories. A key is provided below which should be the starting point for the Stage III decision making. The information in the key is summarized in a flow chart in Figure 5. Use the key or Figure 5 to find the subsection that deals with the waste category to which the waste stream of interest belongs.

The text for each waste category includes a general description of the waste and of the usual disposal practices, followed by a decision tree for estimating the quantity of the waste stream handled by each disposal practice. If the user is unsure which category a particular waste belongs in, then the texts for several possible categories should be read. (In general, this problem is likely to arise only when one is trying to decide whether a given industrial waste is or is not hazardous.)

Two of the waste categories (incinerator residues and POTW sludge) are the products of other treatment/disposal processes. For these wastes, the input information for Stage III will be provided by the Stage V output for wastes that were treated in POTWs or incinerators. Appendix C contains information on the waste disposal practices of the organic chemicals, plastics, and petroleum refining industries that will be useful in Stage III. Appendix D provides information on waste disposal that will aid the user in Stage III decisions.


FROM FIG. 3
IS THE WASTE STREAM INDUSTRIAL ?
NO
IS THE WASTE STREAM RESIDENTIAL OR COMMERCIAL ?
NO
IS THE WASTE A RESIDUE FROM AN INCINERATOR ?
NO
IS THE WASTE A SLUDGE FROM A PDTW* ?
NO
YES
SEE "INCINERATOR RESIDUES", 2.3.3 (1)
YES
SEE "POTW SLUDGE", 2.3.3 (2)
YES
IS THE WASTE A WASTEWATER ?
NO
IS THE WASTE A SOLID WASTE ?
NO
WASTE TYPE IS NOT COVERED BY THIS METHOD (STOP)
YES
SEE "WASTEWATER" 2.3.3 (3)
YES
SEE "MUNICIPAL SOLID WASTE", 2.3.3 (6)
YES
IS THE WASTE A WASTEWATER ?
NO
IS IT A HAZARDOUS WASTE UNDER RCRA ?
NO
SEE "NON-HAZARDOUS INDUSTRIAL SOLID WASTE", 2.3.3 (5)
YES
SEE "WASTEWATER", 2.3.3 (3)
YES
SEE "HAZARDOUS WASTE", 2.3.3 (4)

*PDTW = PUBLICLY OWNED TREATMENT WORKS

FIGURE 5. KEY FOR DETERMING STAGE III STARTING POINT (in Sect. 2.3.3)

The amounts of waste allocated to each disposal practice should add up to the original estimate of the total quantity of the waste stream, and the amounts of waste allocated to each site should add up to the total quantity disposed of at all such sites. However, if total figures and their component quantities were derived from separate sources, then the sum of the components may not equal the independently-derived totals, and some numerical adjustments will have to be made. It is recommended that the preliminary Stage III estimates be made for all applicable disposal practices, followed by Stage IV site-specific estimates for each disposal practice. At that point, all Stage III and Stage IV estimates can be compared and the necessary adjustments made. Note that Stage III can also be used as a screening tool for deciding whether or not exposure from a given disposal practice is likely to be significant. Based on the Stage III estimate and knowledge of general emission factors (if available), some disposal practices may be judged insignificant and not investigated further.

Note that the following key and Figure 5 separate hazardous and nonhazardous industrial waste because the disposal sites and information sources are usually different. The symbol W_A will be used to designate the subject waste stream.

Stage III Key

Step 1. (a) If W_A is ash, scrubber water, or fly ash from an industrial or municipal incinerator, see Subsection (1), Incinerator residues.
(b) If W_A is a wastewater treatment sludge from a POTW, see Subsection (2), POTW sludge.
(c) If W_A is an industrial waste stream (other than those listed above), go to Step 2.
(d) If W_A is a residential/commercial waste stream (other than those listed above), go to Step 3.

Step 2. (a) If W_A is an industrial wastewater, see Subsection (3), Wastewater.
(b) If W_A is a hazardous waste, as defined by the Resource Conservation Recovery Act (RCRA), see Subsection (4), Hazardous waste.
(c) If W_A is neither (a) nor (b), see Subsection (5), Industrial nonhazardous solid waste.

Step 3. (a) If W_A is a residential/commercial wastewater, see Subsection (3), Wastewater.
(b) If W_A is a residential/commercial solid waste, see Subsection (6), Municipal solid waste (MSW).

(1) Incinerator residues. Background information on the secondary products of incineration that require further treatment/disposal is presented in this section, followed by a decision tree for estimating the probable disposal practice.

(a) Background information. Incineration of waste produces several kinds of releases besides the gases and particulates that are discharged directly into the atmosphere. Residue composed of uncombusted and inert material, fly ash collected by air pollution control equipment, and aqueous solutions from various sources are produced in varying quantities during controlled incineration. These wastes may contain chemical substances that were in the incinerated waste or were formed during incineration. Unfortunately, there is relatively little quantitative or qualitative information on the fate of chemical substances in incineration processes. It is clear, however, that the following variables influence the fate of toxic substances during incineration and, hence, the amounts contained in the residuals: (1) physical and chemical characteristics of wastes; (2) design and operation of incinerators; and (3) design and operation of pollution control equipment. These factors are discussed below for each product of incineration. See Section 7 for additional information on incineration.

Ash is the residue remaining after incineration and includes both the bottom ash that remains in the combustion chamber and the fly ash that is entrained in the exhaust gases leaving the incinerator. In incinerators with effective air pollution control equipment, most of the fly ash is captured and must be disposed of to land. If incineration results in complete combustion, the ash will consist almost exclusively of inert matter. In practice, however, incomplete mixing of wastes in the combustion chamber often occurs, resulting in incomplete combustion.

Table 2 gives typical characteristics of residue from municipal incinerators. This table may provide useful generic data for a detailed exposure assessment in which the amount of a chemical left in the residue after MSW incineration is of interest. For instance, if the consumer product of concern is paper containing a toxic chemical, then one can assume that no more than 1.8 percent of the residue will contain the subject chemical. In one study of municipal incinerators, unburned combustibles ranged from 0.1 to 1.3 percent of the residue in four incinerators; in the fifth incinerator, 35.8 percent of the residue was unburned combustibles (Rubel 1974). (An overloaded furnace and the lack of proper agitation contributed to the high value.) Approximately 6 percent to 10 percent of the residue from municipal incinerators is water soluble and therefore subject to leaching if improperly disposed of on land. Typical constituents in the water-soluble portion are presented in Table 3. The fly ash from municipal incinerators is also variable in composition, the organic matter ranging from 5 to 30 percent of the total. The chemical profile of fly ash from one municipal incinerator is given in Table 4.

Table 2. Characteristics of Municipal Incinerator Residue from Two Studies[a]

Component	Percent by weight
Ferrous metal	15.75
Magnetic flakes	3.80
Nonferrous metal	0.30
Glass over 1/4 inch	9.48
Ceramics, stones	1.51
Clinkers	24.11
Ash, nonmagnetic	16.10
Combustibles	
Paper, wood, char	1.79
Putrescible (visual)	0.07
Bones, pits	0.03
In conveyor water	27.06
TOTAL	100.00

Material	Percent by weight (range)
Metals	19-30
Glass	9-44
Ceramics, stones	1-5
Clinkers	17-24
Ash (exclusive of other materials listed)	14-16
Organic	1.5-9

[a] The upper table is based on the analysis from a 300-ton-per-day continuous feed incinerator. The data in this table are not meant to represent average or typical residue compositions, but can be used as a "first guess" in estimating residue composition.

The lower table presents typical ranges of values for the various residual constituents.

Source: Rubel 1974.

Table 3. Average Analysis of Water-Soluble Portion of Residue from Selected Municipal Incinerators[a]

Constituent	Batch-feed incinerator[b]		Continuous-feed incinerator[b]	
Hydrocarbon concentration	6.1666	(92.9132)	9.1666	(92.2602)
Alkalinity	0.1156	(1.7418)	0.1865	(1.8771)
Nitrate nitrogen	0.0004	(0.0060)	0.0003	(0.0030)
Phosphate	0.0002	(0.0030)	0.0004	(0.0040)
Chloride	0.1221	(1.8397)	0.0771	(0.7761)
Sulfate	0.0813	(1.2250)	0.2447	(2.4629)
Sodium	0.04675	(0.7044)	0.197	(1.9828)
Potassium	0.04230	(0.6373)	0.048	(0.4831)
Iron	0.0617	(0.9296)	0.015	(0.1510)

[a] The water-soluble portion of residue is of interest because of the potential for water pollution from residue landfill sites by leaching. Most residue constituents listed in Table 2 may include a small water-soluble fraction.

[b] Percent by dry weight of total residue (water-soluble and insoluble). Percent by dry weight of water-soluble portion in parentheses.

Source: Rubel 1974.

Table 4. Chemical Analysis of Fly Ash Samples from a Municipal Incinerator[a]

Component	Percent by weight
Organic	10.4
Inorganic	89.6
Silica as SiO_2	36.1
Iron as Fe_2O_3	4.2
Alumina as Al_2O_3	22.4
Calcium, as CaO	8.6
Magnesium as MgO	2.1
Sulfur as SO_3	7.6
Sodium and potassium oxides	19.0

[a] Based on samples from South Shore Incinerator in New York City. Other studies have shown that flyash can consist of an average of from 5 to 30% organic matter and from 70 to 95% inorganic matter.

Source: Rubel 1974.

Ash from sewage sludge incineration is generally composed of inert matter. Ash from hazardous waste incinerators, however, is considered hazardous under RCRA regulations (see Section 2.3.3(4)) unless testing shows otherwise. Although most ash of this type consists largely of inert compounds, the composition varies greatly. The relative proportion of fly ash to bottom ash depends on the waste composition and the design and construction of the hazardous waste incinerator (Monsanto 1981).

Incinerator ash is generally disposed of on land; however, the exact disposal patterns for various ashes have not been determined. The bulk of municipal incinerator ash is probably disposed of in landfills, as is bottom ash from sewage sludge incineration (Walker 1979). Fly ash is disposed of in either lagoons (with effluent treatment) or landfills (USEPA 1979a). Sludge incineration ash is sometimes used as a conditioning agent in sludge treatment processes. Bottom ash from the incineration of hazardous wastes can be disposed of in landfills approved for hazardous wastes. The fly ash is usually disposed of with the scrubber water, as explained below.

Water is used in various stages of the incineration process and usually becomes contaminated with dissolved and suspended matter, requiring treatment prior to discharge (Rubel 1974). Scrubbers clean the combustion gases by carrying wetted fly ash (which may contain small amounts of organics) to the bottom of the scrubber. The fly ash and scrubber effluent are discharged to lagoons or sanitary landfills (USEPA 1979a). In hazardous waste incineration facilities, the scrubber effluent (containing fly ash) is combined with the quench water (which does not generally contain hazardous constituents), and treated on-site. This wastewater may contain chlorides, fluorides, sulfites, sulfates, phosphates, bromides, and bromates in addition to the particulate matter. Treatment normally involves clarification, neutralization, and dilution. Suspended solids are often removed in on-site settling ponds. In sufficiently dry geographical areas, the scrubber wastewater can be treated in evaporation ponds, after which the sludge may be taken to a landfill for ultimate disposal. Alternatively, the wastewater may be discharged to a POTW providing that national and local pretreatment standards are met (Monsanto 1981).

(b) Stage III decision tree for incinerator residues. The input to this stage will be the information on amounts and subject chemical concentrations in incinerator residues that is the output of Stage V for incineration (see Section 7.3).

Because the amounts of toxic chemicals present in incinerator residue will often be very low and because there is little precise information on disposal practices for these wastes, the user should carefully evaluate the expected loadings before expending considerable effort to proceed with the method. One or all residual products may be discounted as unworthy of further consideration as a potential source of human exposure.

In this decision tree, the user evaluates the available information on the waste disposal practices used for incinerator residues for the various waste categories. Then the amount of the subject waste disposed of by each likely practice is estimated.

Step 1. Determine which disposal practices are used for disposal of incinerator residues.

The available literature suggests that landfills and surface impoundments are the only practice currently used for disposal of bottom ash. Quench waters and scrubber waters may be treated by a variety of standard wastewater treatment methods, including lagoons; treated effluent may be discharged directly to surface waters, to POTWs, or to evaporation ponds. The sludge from storage lagoons is generally landfilled.

Step 2. Considering the available information, estimate the percentage of incinerator residues that will be disposed of by each practice.

The following guidance is based on limited information. It should be used only if more specific information is not available.

- Bottom ash. In the absence of quantitative information to the contrary, assume that all bottom ash from municipal and sewage sludge incinerators is landfilled. Assume that all bottom ash from industrial incinerators is also landfilled, unless the available industry-specific documents on waste disposal practices indicate otherwise (see Table 8 under "Hazardous Waste" (Subsection (4)). For ashes produced from incineration of industrial hazardous waste, assume ultimate disposal is in a landfill designed for hazardous waste, unless the above-mentioned documents suggest differently.

- Fly ash. The information on fly ash disposal is so sparse that any assumptions may be suspect. More fly ash than bottom ash is probably treated or disposed of in lagoons. In the absence of data to the contrary, it may be assumed that 50 percent is treated in lagoons and 50 percent is transported directly to landfills for disposal. A significant portion of the fly ash treated in lagoons may require ultimate disposal in a landfill. Assume that fly ash from incineration of hazardous wastes is treated in lagoons or landfills designed for hazardous wastes (see Subsection (4)).

- Scrubber water and other wastewaters. For incinerator ash from POTWs (see Subsection (2)) and municipal incinerators, assume that the water is treated by the POTW. For industrial incinerators, assume that the same proportion is treated on-site as for other wastewaters of the same industry (see Subsection (3), Wastewater).

(2) POTW sludge. A description of the sources, characteristics, and disposal practices associated with municipal wastewater treatment sludge (POTW sludge) is presented here, followed by a decision tree for estimating the amounts of sludge handled by the various available disposal options.

(a) Background information. The process of wastewater treatment produces a sludge composed of the materials that settled from the raw wastewater (such as sticks, organic solids, and rags), as well as solids actually generated in the wastewater treatment process (such as excess activated sludge or chemical sludge produced by advanced treatment). Some typical constituents of sludges are given in Table 5. In general, the sludge generation rate increases with increasing levels of wastewater treatment, from primary to advanced wastewater treatment; typical sludge generation rates as a function of total wastewater flow and treatment level are presented in Table 34 in Section 6.

When sludge is withdrawn from treatment processes, it is composed largely of water (up to 97 percent) (Culp 1979), some of which is removed in subsequent treatment. The primary purpose of sludge treatment processes is to separate large amounts of water from solids; treatment may include the following:

- Conditioning - treatment of the sludge with chemicals or heat so that the water can be easily separated.
- Thickening - separation of waste by gravity or flotation.
- Dewatering - further separation of water using vacuum pressure or drying processes.
- Stabilization - digesting the organic solids so that they can be handled or used as solid conditioners without causing a nuisance or health hazard.
- Reduction - reduction of solids by wet oxidation processes or incineration.

See USEPA (1980g) for an in-depth description of various sludge treatment and disposal methods. The final water content of treated sludge will vary depending on the treatments used. The only treatment

Table 5. Average Characteristics of Sewage Sludge

Material	Combustibles (%)	Ash (%)	BTU/lb
Grease and scum	88.5	11.5	16,750
Raw sewage solids	74.0	26.0	10,285
Fine screenings	86.4	13.6	8,990
Ground garbage	84.8	15.2	8,245
Digested sewage solids and ground garbage	49.6	50.4	8,020
Digested sludge	59.6	40.4	5,290
Grit	30.2	69.8	4,000

Source: Rubel 1974.

process considered in detail in this volume is reduction by incineration, which usually requires a moisture content of less than 70 percent for the combustion to be self-sustaining. (See Table 37 in Section 7 for information on the typical moisture content of sludges treated by incineration.)

Sludge treatment and disposal can be a source of exposure to chemical substances because of the tendency of sludges to accumulate metals and nonvolatile organics that were present in the wastewater. An EPA study of toxic chemicals in POTW wastewaters and sludges (Burns and Roe 1982) has reported that numerous priority pollutants have been found in POTW sludges at much higher concentrations than those measured in the influent wastewater (see Tables H-4 and H-7 in Appendix H).

The major disposal practices used for POTW sludges and the amounts of sludge handled by each practice are given in Table 6. Estimates vary, however, depending on the method of estimation; for example, some authors consider lagoons to be a disposal option, while others treat them as storage facilities prior to ultimate disposal by landfilling. Similarly, incineration is usually listed as a disposal practice (rather than a treatment practice), with little consideration given to the ultimate disposal of the residues. For the purposes of this volume, the Needs Survey (Exhibit H-1 in Appendix H) coupled with the Surface Impoundment Assessment (SIA) data base (Section 5) and surveys of municipal sludge incinerators will generally be sufficient to determine both disposal practices and the general locations of sludge incinerators and lagoons. There are no good sources of data on exact locations of landspreading sites or landfills receiving POTW sludges, although reasonable assumptions might be made based on the fact that it is expensive to haul sludge great distances. The ultimate fate and exposure from sludge that is ocean-disposed or distributed for marketing will not be explored in this method. Neither will such uncommon treatment practices as composting, pyrolysis (thermal decomposition in the absence of oxygen), and coincineration be discussed. As Table 6 indicates, all of the uncommon sludge disposal practices combined (including disposal in lagoons) handle only 12 percent of the POTW sludge generated.

(b) Stage III decision tree for POTW sludge. The user will need the following information on the subject sludge from the Stage V output of the POTW analysis (Section 6.3): amount and sources of sludge (including geographic location), possible concentrations of chemical substances, and other physical/chemical characteristics such as the moisture content. Using this information and Steps 1 and 2 below, the disposition of the sludge to the various disposal methods can be estimated.

Table 6. Current Nationwide Disposal Practices for POTW Sludge

Disposal Method	Percentage, by weight, 1980[a]
Ocean disposal	4
Incineration	27[b]
Landspread on non-food chain land	12
Landspread on food chain land	12
Landfill	15[b]
Distribution for marketing	18
Other	12[c]

[a] Based on most recent estimates (personal communication with M. Flynn, EPA Office of Solid Waste, September 24, 1981).

[b] Based on 1978 estimates, the bulk of the ash is ultimately disposed of in landfills (Walker 1979). If this is still true, the landfilled estimate is too low.

[c] Based on 1978 estimates, the bulk of this category is probably disposed of in surface impoundments (Walker 1979).

Step 1. **As a first cut, look at Table 6 to determine the major disposal options and the quantities of sludge handled by each practice.** In a very general, nationwide exposure assessment, the figures in Table 6 may suffice. For accurate information based on site-specific data, however, go to Step 2.

Step 2. **If a detailed exposure assessment is required, examine site-specific data in order to estimate the amount of the subject sludge disposed of by each practice.**

A detailed exposure assessment that evaluates exposure on a local or regional basis will require information that was compiled by the Needs Survey (Section 6 and Exhibit H-1 in Appendix H), which contains site-specific data for each POTW in the U.S. Therefore, an accurate Stage III estimate of sludge disposal practices will be based on the site-specific data obtained in Stages IV and V of the POTW evaluation (Sections 6.2 and 6.3). This is a case where Stage III cannot be estimated until Stage IV has been completed. One complete Needs retrieval, providing both the site-specific data needed for Stage IV and the summary statistics needed for Stage III, should be conducted, as outlined in Section 6. The Needs Survey contains detailed information on the sludge treatment/disposal practices at each POTW. Table H-8 in Appendix H lists all of the sludge treatment parameters used in the Needs Survey data base. Summary statistics on the total wastewater flow produced by each wastewater treatment process and treated by sludge disposal practice are available from Needs. The user can apply the sludge generation factors given in Table 34 in Section 6 to convert these flows to volumes of sludge. The final output of Stage III should include the total sludge volume, concentration of chemical substance, and other physical/chemical characteristics of the sludge disposed of by each practice of interest in the study area. The uncertainty in the quantitative output of this step depends on the accuracy of the site-specific Needs estimates and the sludge generation factors.

(3) Wastewater. This section contains the information necessary for determining how much of a given commercial, residential, or industrial wastewater will be treated at a municipal wastewater treatment plant (POTW). Note that industrial wastewater treated on-site is not covered in this volume; rather this source is included as a point source in Section 6.3 of Volume 2 (ambient exposure scenario). A general discussion of wastewater is presented first, followed by the decision tree.

(a) Background information. Wastewater is generally treated and disposed of by entirely different practices from those used for solid waste. Wastewaters can be grouped into five categories based on their origin: residential, commercial, industrial, stormwater, and groundwater. Only the first three categories are true waste streams. Exposure to chemical substances in stormwater is considered in the ambient exposure assessment volume (Volume 2). Groundwater seepage into sanitary sewers results when groundwater enters sewer pipes through cracks or loose joints. Such seepage is most prevalent in older sewer systems and does not generally contribute significant levels of toxic chemicals to municipal wastewaters. Therefore, this process is not treated explicitly in any of the volumes of this series. A brief description of residential, commercial, and industrial wastewaters and the treatment/disposal practices most commonly applied to them is presented below.

Residential wastewater comprises all wastes entering sewers from homes. The primary source of chemical substances in residential wastewater is probably consumer products that are washed into drains from bathtubs, sinks, and washing machines. Chemicals may also leach from components of the plumbing system. Residential wastewater is generally disposed of through municipal sanitary sewers or on-site septic tanks/leachfields. Some residential wastewaters are discharged directly to land or surface waters. Commercial wastewaters originate from office buildings and nonmanufacturing industrial facilities. Although much of this waste is similar in composition to residential waste, significant levels of toxic chemicals may be contributed by such industrial sources as film developers, testing laboratories, service stations, and dry cleaning establishments. Some commercial wastes are treated on-site, others are routed to POTWs, and some are discharged directly to surface waters. The annual Needs Survey conducted by the Priority Needs Branch of the EPA Office of Water Program Operations (see Exhibit H-1 in Appendix H) does not give a breakdown on the relative contributions of residential and commercial wastewaters to POTWs; these two types are combined under the "domestic" category.

Industrial wastewaters originate at manufacturing or processing facilities and may consist of large volumes of water used in manufacturing and processing industrial products. Industries also produce sanitary and nonprocess wastewaters. Industrial wastewaters may be discharged either directly to surface waters with or without prior on-site treatment, or indirectly (i.e., to POTWs). (The distinction between direct and indirect discharge should be borne in mind throughout the following discussion.) Industrial wastewaters may also be treated by other means, such as on-site septic tanks/leachfields, injection wells, or land treatment, and not discharged to surface waters at all. Special effluent guidelines governing the quality of effluents discharged to surface waters have been developed for the 21 major industries identified by the EPA as producing effluents containing significant amounts of toxic substances; these industries are listed in Table D-8 in Appendix D. In addition, pretreatment standards regulating the quality of effluent discharged to POTWs are being developed for these industries.

Of the various disposal practices used for wastewaters, only the disposal by municipal collection and treatment systems, injection wells, and land treatment are considered in detail in this volume. Exposure to chemical substances via industrial and commercial on-site wastewater treatment with discharge to ambient waters (i.e., direct discharge) is covered by Volume 2 of this methods development series. The potential for exposure to chemicals as a result of leaching from septic tank waste is not discussed in this report.

Nationwide, about 73 percent of wastewaters treated by POTWs are of domestic (residential or commercial) origin, the balance being contributed by industrial plants (USEPA 1981e). Seventy percent of the U.S. population is served by POTWs (see Table 7). The extent of industrial wastewater treatment by POTWs varies, however, ranging from treatment plants that receive no industrial effluents to plants that are operated jointly by a sewage authority and an industry, treating a large volume of industrial wastewaters. The degree to which industrial wastewaters are discharged to surface waters indirectly (via POTWs) depends on many factors, including the treatment capability of the local POTW, the nature of the industrial wastewaters, cost considerations on the part of both the industry and the sewage authority, and federal and state policy and regulations. The EPA has developed extensive documentation for the industrial wastewater treatment practices of the 21 major industrial categories (see Volume 2, Section 6.3 of this methods development series). These studies provide useful generic data on industries that can be used for exposure assessments when site-specific information is not available. As a result of the National Pollution Discharge Elimination System (NPDES), however, site-specific information is available for all facilities that discharge to surface waters. These data are available in computerized form through several EPA data bases including the Permit Compliance System (PCS) and the Industrial Facilities Discharge File (IFD), and can be used to extract both generic information on industries and site-specific information on permit holders.

(b) Stage III decision tree for wastewater. Ideally, the input to this stage will be Stage II estimates of wastewater flow, concentration of the subject chemical in the wastewater, and related information on the source of the wastewater. In some cases, however, the user may know only the quantity of the subject chemical discharged to

Table 7. Populations Served by Wastewater Treatment Types

Type of treatment	Number of persons ($\times 10^6$)	Number of POTWs	Percent of total population
No treatment	67.1	0	30.0
Treatment but no discharge to surface waters	3.6	1,361	1.6
Preliminary	2.3	272	1.0
Primary	37.3	3,343	16.6
Secondary	62.7	7,852	28.0
Advanced secondary	47.5	2,443	21.2
Tertiary	4.9	251	2.1

Source: USEPA 1981e.

wastewater from a given source. In this stage, available information will be used to determine whether the subject wastewater will be treated at a POTW, based on the source of the wastewater. Then the user will estimate the actual amount of wastewater likely to be treated at POTWs. An additional step for estimating the concentration of the chemical in the wastewater is given for cases where concentration is needed but not provided by the Stage II output.

Step 1. Estimate the proportion of the subject waste stream that will be disposed of by POTWs. (See 1.a for domestic wastewater and 1.b for industrial wastewater.)

a. Domestic wastewater. For a nationwide exposure assessment it can be assumed that 70 percent of the U.S. population is served by POTWs (Table 7). For assessments of regional or statewide scope, consult the published annual summaries of the technical Needs Survey data base (USEPA 1981e). This presents, among other things, the percentage of the resident population in each state that is served by POTWs and the total domestic flow treated by POTWs in each state; these data are also summarized in Appendix D, Tables D-1 and D-2.

For detailed assessments where greater geographic resolution is required, a computerized retrieval from the Needs Survey data base is recommended (see Exhibit H-1 in Appendix H). This provides the same kind of data discussed above for POTWs within small geographic areas (e.g., county, Congressional district, sewer district). This retrieval can be conducted so as to satisfy the requirements of the Stages IV and V decision trees for POTWs as well, by requesting, in the same operation, information on the parameters listed in those decision trees (see Sections 6.2 and 6.3).

b. Industrial wastewater. The likelihood that a given industrial wastewater will be treated at a POTW depends on the industry and the local sewage authority. Industrial wastewaters may be treated by a POTW provided that the sewage authority has given the plant a permit to discharge indirectly. Industries that are among the 21 major industries (see Table D-8 in Appendix D) must meet pretreatment standards in order to be permitted to discharge to a POTW. When site-specific data are not required (as in the case where the exposure assessment is general in nature), the wastewater disposal practices of the industry as a whole (or for the appropriate subcategory) can be used as surrogate data if the industry has been studied by the Effluent Guidelines Division (EGD) of EPA. This information can be obtained from various publications, such as the development documents series, for the 21 major industries. (See Section 6.3 of Volume 2 for a list of relevant EGD publications.) For exposure assessments where site-specific information is required, however, a computer retrieval from the IFD file is recommended (see Exhibit H-2 of Appendix H). This will provide information in a single operation for both Stages III (for wastewater in general) and IV (for POTWs); refer ahead to Stage IV, Step 1 for POTWs (Section 6.2) for guidance.

Step 2. Estimate the concentration of the chemical of interest in the wastewater treated by POTWs, if it is not already provided by available information. (See 2.a for domestic wastewater and 2.b for industrial wastewater.)

a. Domestic wastewater. Concentration of the subject chemical in domestic POTW influent can be determined using Tables D-1 and D-2 in Appendix D. Which table to use depends on the type of data that was originally used (probably in Stage II) to determine the total mass of the subject chemical in all domestic wastewaters. If this estimate was based on the per capita use of a product containing the subject chemical (e.g., mass of product used per person per day), then Table D-1 should be used, since it is based on population data. If the estimate was based on the average concentration of the subject chemical found in all domestic wastewaters (e.g., mg chemical per liter of wastewater), then Table D-2 should be used, since it represents directly the total amount of wastewater treated at POTWs. Data from Tables D-1 and D-2 can be used in the following equations:

$$P = A \times B \qquad (2\text{-}1)$$
$$F = P \times G_W \qquad (2\text{-}2)$$
$$Q = P \times G_C \qquad (2\text{-}3)$$
$$C = Q \div F \qquad (2\text{-}4)$$

where

P = population contributing the subject wastewater to POTWs
A = population served by POTWs (from Table D-1)
B = fraction of population using a product containing the subject chemical
F = flow of subject wastewater (volume/day)
G_W = per capita wastewater generation (from Table D-2) (Volume per cap./day)
G_C = per capita disposal of subject chemical (mass per cap./day)
Q = total quantity of subject chemical routed to POTWs (mass/day)
C = concentration of subject chemical in waste stream (mass/volume).

For a detailed assessment requiring geographic resolution beyond the state level, a computerized retrieval of the parameters A and G_w from the Needs Survey data base is recommended as input to Equations 2-1 through 2-4.

b. Industrial wastewater. The total mass of the subject chemical released to wastewater should have been determined in Stages I and II. The proportion of this chemical treated by POTWs will also have been provided by Stages I and II, or else by Step 1 above. The concentration of the subject chemical in industrial POTW influent can then be calculated as follows, if not already provided by the Stage II information sources (Equation 2-5).

$$C = \frac{M}{F} \tag{2-5}$$

where

C = concentration
M = mass of chemical treated at POTWs
F = wastewater flow to POTWs from subject industry

(4) Hazardous waste. Background information on hazardous waste is presented below, followed by the Stage III decision tree for allocating hazardous wastes to likely disposal methods.

(a) Background information. Hazardous waste is defined by Title 40 of the Code of Federal Regulations (40 CFR Part 261). To be considered hazardous, a waste must be named in the list of specific hazardous waste streams and chemicals provided in the cited regulation, or it must exhibit one or more of certain specific characteristics which include ignitability, corrosivity, reactivity, and toxicity. The definition excludes household waste, agricultural waste returned to the soil, and mining overburden returned to the mine site. It also excludes all wastewater discharged directly or indirectly to surface waters, since this is regulated by other legislation. (It should be noted, however, that, although hazardous waste is considered a solid waste by EPA definition, a large part of it is physically in the liquid state.) About 20 percent of the total of 41.2 million wet metric tons (kkg) of hazardous waste generated yearly is known to be specifically included in the EPA hazardous waste list (USEPA 1980f).

Permits are required for the storage, treatment, and disposal of hazardous waste under Subpart C of the Resource Conservation and Recovery Act (RCRA). Permitting authority may be ceded to the state if EPA determines the state's hazardous waste regulatory program to be "substantially equivalent" to that of EPA (40 CFR Part 123.128). Identifying the agencies that have jurisdiction over the disposal of a subject waste will facilitate the assessment procedure, since they may be important sources of relevant data (as discussed below). It is also important to be familiar with the regulations themselves, since they may dictate performance standards or design/operational features of hazardous waste disposal facilities; in the absence of reliable site-specific data, these requirements can be used as input parameters for various stages of the assessment (assuming compliance with the regulations). Regulations also influence the generation and disposal patterns of hazardous waste by their effect on the cost-benefit ratio of disposal options. The most recent hazardous waste regulations were promulgated in July 1982 (USEPA 1982b). Nationwide trends relating to the generation and disposal of such waste will be affected by any changes in these regulations. Therefore, many estimates and assumptions incorporated into this volume may have to be modified in the future.

Almost all industries generate hazardous waste, but the chemical industry is the major source, contributing 60 percent of the total (USEPA 1980f). Other major contributors include the primary metals, petroleum and coal products, and fabricated metal products industries. Generation of hazardous waste within a region reflects the particular makeup of industry in that region. About 23 percent of hazardous waste is treated off-site by commercial hazardous waste handlers (USEPA 1980b).

In general, half of all hazardous waste goes to surface impoundments, about 40 percent to landfills, and the rest to incinerators, land treatment, and injection wells. Some treatment methods produce new hazardous waste requiring ultimate disposal; these include incineration producing toxic ash and wastewater treatment producing toxic sludge. Possible disposal methods for the various types of hazardous waste are summarized in Table 8. In some cases, e.g., Iowa and Kansas, manufacturers apply to the state for permission to dispose of their hazardous waste and are directed where to do so. Nevertheless, about 9 percent of the nation's hazardous waste may be improperly diverted to municipal landfills not designed for its acceptance (Van Noordwyk 1980). This practice may be especially common in areas with few or no permitted hazardous waste disposal sites (USEPA 1980b).

Table 8. Hazardous Waste: Possible Disposal Methods

Solid Waste

- Landfill
- Incineration[a]

Sludge

- Landfill
- Incineration[a]
- Landspread
- Surface Impoundment
- Injection well
- POTW

Liquid Waste

- Landfill
- Incineration[a]
- Surface Impoundment
- Landspreading
- Injection well

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[a] For ultimate disposal of incinerator ash, see Section 2.3.3(1).

Major sources of data on hazardous waste generation patterns include the various RCRA background documents, available from EPA, and the series of industrial hazardous waste assessment reports produced for the EPA Office of Solid Waste (OSW) (see Table 9). Additional sources of information are the reports on waste generation issued by a number of individual states. A list of state reports obtained in this study is given in Appendix B, Exhibit B-1. For additional information, the state agencies should be contacted; state solid waste agencies are listed in Appendix D, Table D-3.

A major source of information on both generation and disposal of hazardous waste is the Hazardous Waste Data Management System (HWDMS). This data base is maintained by the EPA State Programs and Resource Recovery Division of the Office of Solid Waste (OSW) and contains data from RCRA permit applications. See Appendix D, Exhibit D-1 for a discussion of HWDMS. A recent summary of the population of hazardous waste sites listed in HWDMS by treatment/storage/disposal method is given in Appendix D, Table D-7. In addition, several states maintain their own lists of permitted hazardous waste disposal sites.

(b) Stage III decision tree for hazardous waste. The input to this stage will be the volume or mass, chemical concentration, source, and other physical/chemical information for the subject waste stream, derived from the output of Stage II. The following references will be useful:

- RCRA background documents
- All OSW industrial waste disposal assessments (see Table 9)
- Any relevant state surveys or reports (see Appendix D, Table D-3 and Appendix B)
- HWDMS data base
- Appendices C and D to this report.

The user will evaluate available information on the disposal practices used by the industry that generates the waste as well as the characteristics of the waste. This information is used to estimate the amount handled by each disposal practice.

Step 1. Determine the probable distribution of the subject waste stream among disposal types, based on generic data.

Compile all relevant estimates from each reference source above. List available estimates, and decide which to use based on how recent the data are, the estimated reliability of the data collection methods, or other factors. If appropriate, estimates from different sources can be combined and averaged. Estimates thus obtained may be sufficient for

Table 9. OSW Industrial Hazardous Waste Assessment Reports

Industry	SIC	Prepared by	Date	EPA no.	NTIS no.
Metals mining	10	Midwest Research Institute	9/1976	SW 132c	PB 261 052
Textiles	22	Versar, Inc.	6/1976	SW 125c	PB 258 953
Inorganic chemicals	281	Versar, Inc.	3/1975	SW 104c	PB 244 832
Rubber and plastics	282,30	Foster D. Snell, Inc.	3/1978	SW 163c.1-4	PB 282 070-073
Pharmaceuticals	283	Arthur D. Little, Inc.	1976	SW 508	PB 258 800
Paint and allied products	285	Wapora, Inc.	9/1975	SW 119c	PB 251 669
Organic chemicals, pesticides, explosives	286,2879 2892	TRW Systems	1/1976	SW 118c	PB 251 307
Petroleum refining	2911	Jacobs Engineering Co.	6/1976	SW 129c	PB 259 097
Petroleum re-refining	2992	. . .	1977	SW 144c	PB 272 267
Leather tanning and finishing	3111	SCS Engineers, Inc.	11/1976	SW 131c	PB 261 018
Metal smelting and refining	33	Calspan Corp.	4/1977	SW 145c.1-4	PB 276 169-172
Electroplating and metal finishing	3471	Battelle Columbus Labs	9/1976	SW 136c	PB 264 349
Special machinery manufacturing	355,357	Wapora, Inc.	4/1977	SW 141c	PB 265 981
Electronics components manufacturing	367	Wapora, Inc.	1/1977	SW 140c	PB 265 532
Storage and primary batteries	3691,3692	Versar, Inc.	1/1975	SW 102c	PB 241 204

Source: Van Noordwyk 1980.

exposure assessments that do not require great depth of detail in the disposal setting. For more detailed or site-specific assessments, proceed to the following steps.

Step 2. Compile the names and locations of all facilities receiving the subject waste stream.

This may be accomplished by conducting an HWDMS retrieval for the geographic area of interest (see Appendix D, Exhibit D-1). Use the Standard Industrial Classification (SIC) code for the industry that generates the subject waste stream, as well as the SIC code for commercial (off-site) waste handlers (4953) or the commercial "tag" mentioned in Exhibit D-1.

Step 3. Confirm or correct the gross estimates from Step 1 using HWDMS data.

The retrieval conducted in Step 2 provides only facility names and locations. In order to determine the specific treatment types employed at these locations, consult the complete HWDMS printout of permit application data; this must be consulted manually at the EPA Office of Solid Waste. It lists the treatment, storage, or disposal practices used at a given hazardous waste facility (process code), as well as the proposed capacity, arranged by location (zip code). Use this information to confirm or correct the gross estimates from Step 1. For example, if most generators of the subject waste have on-site hazardous waste disposal capacity, it can be assumed that all of their waste stays on-site and is treated by the practice listed in their permit application.

Step 4. If data collected thus far are insufficient, skip ahead to Stage IV for the disposal practices of interest; information obtained there may be applied to Stage III. In any case, after Stage IV is completed, return to Stage III and make any necessary adjustment. If the Stage IV procedures do not provide the desired information, estimate the quantity of waste handled by each applicable disposal practice based on available information on the waste disposal practices of similar industries or on the relative proportions of different types of hazardous waste disposal facilities available in the area. Note that hazardous waste may be diverted to facilities not permitted for it.

The output of this step will be a list of the disposal practices likely to receive the waste stream of interest and estimates of the amounts of the waste disposed of by each practice in units of mass/year.

(5) Nonhazardous industrial solid waste. This category includes all nonhazardous (i.e., not designated as hazardous by RCRA) solid waste materials from factories, processing plants, and other manufacturing enterprises. It also includes sludges and liquid wastes not discharged to sewers. General information on this waste category is presented in (a), followed by the Stage III decision tree (b).

(a) Background information. A total of 56.3 million metric tons (kkg) of solid waste (hazardous and nonhazardous) are generated annually (Table 10). The largest generators are the fabricated metals, chemical, nonelectrical machinery, rubber, and plastics industries. A total of 8.4 million metric tons of industrial sludge are generated annually (Table 11); 90 percent of this is produced by three sources, the nonelectrical machinery, chemical, and textile mills industries. The nonelectrical machinery industry alone generates 50 percent of the total.

Industrial wastes are difficult to quantify because they are usually of a unique character, peculiar to a specific industry and often to a specific plant. Typical wastes include spent solvent; discharged products, spills, and sweepings; unwanted by-products, fractions, or residues from distillation or other processes; wastewater and cooling tower sludges; and empty containers.

Solids are generally landfilled or incinerated. Liquids may be incinerated, kept in surface impoundments, or landspread; they may also be drummed and landfilled, provided that the landfill possesses a synthetic liner and a leachate collection and recovery system (40 CFR Parts 264-265). Sludges may be treated by any of these practices, as well as by ocean dumping; occasionally, industrial sludges are sent directly to a POTW or are sold as soil conditioner or fertilizer. Residue resulting from incineration is discussed in Section 2.3.3(1). Possible disposal practices for industrial wastes are summarized in Table 12.

Treatment, storage, and disposal of nonhazardous solid waste are regulated under Subtitle D of RCRA. In general, guidelines and regulations governing nonhazardous solid waste are less stringent than those governing hazardous waste.

To date, the disposal of nonhazardous industrial waste has received relatively little attention. Consequently, very few data quantifying the relevant waste generation and disposal practices are available. Because disposal problems are handled by the individual firms, the exact practices used for disposal are as varied as the industries themselves. In addition, wastes are often disposed of on-site, making assessment of the disposal practices more difficult to quantify.

Table 10. Industrial Solid Waste Production[a]

SIC Code	Industry	Metric tons per year
22	Textile mill products	1,642,105
23	Apparel	2,412,150
24	Wood products	4,581,679
25	Furniture	1,004,846
26	Paper and allied products	2,134,034
28	Chemicals and allied products	6,817,586
29	Petroleum	203,897
30	Rubber and plastics	5,237,397
31	Leather	1,957,157
32	Stone, clay	3,443,644
33	Primary metals	3,152,288
34	Fabricated metals	8,801,146
35	Non-electrical machinery	5,725,367
36	Electrical machinery	4,058,142
37	Transportation equipment	3,728,091
38	Professional and scientific instruments	805,628
39	Miscellaneous manufacturing	572,971

[a] Includes hazardous waste; excludes sludge.

Source: USEPA 1980b.

Table 11. Sludge Generation[a] by Manufacturing Industries

SIC Code	Industry	Metric tons per year
22	Textile-mill products	1,147,334
23	Apparel	0
24	Wood products	0
25	Furniture	0
26	Paper and allied products	6,441
27	Printing, publishing	0
28	Chemicals and allied products	1,964,814
29	Petroleum	363[b]
30	Rubber, plastics	45,451
31	Leather	0
32	Stone, clay	5,897
33	Primary metals	418,673
34	Fabricated metals	70,852
35	Non-electrical machinery	4,404,002
36	Electrical machinery	0
37	Transportation equipment	277,966
38	Professional and scientific instruments	0

[a] Includes hazardous sludge.

[b] Estimate based on only one observation.

Source: USEPA 1980b.

Table 12. Nonhazardous Industrial Solid Waste: Disposal Methods

Solid Waste

- Landfill
- Incineration[a]

Sludge

- Landfill
- Incineration[a]
- Landspreading
- Surface impoundment
- POTW[b]
- Injection well
- Ocean

Liquid Waste, to Land

- Landfill
- Incineration[a]
- Surface impoundment
- Injection well
- Landspreading

---

[a] For ultimate disposal of incinerator residue, see Section 2.3.3(1).

[b] This practice is not very widespread and will not be examined in detail in the methodology.

Since hazardous waste disposal is relatively well documented, and nonhazardous waste is frequently disposed of in hazardous waste streams, it may be assumed that, in some cases, they are disposed of in a roughly similar fashion. The sources of information on industrial waste generation and disposal are the same as for hazardous waste, which are described in Section 2.3.3(4).

(b) Stage III decision tree for nonhazardous industrial wastes. The same basic procedure is used to determine the likely disposal practices for nonhazardous industrial waste as for hazardous wastes except that there is less information on nonhazardous waste. The following sources of information should be used:

- RCRA background documents (see Subsection (4))
- All OSW hazardous waste assessments (see Table 9)
- Any relevant state surveys or reports (see Appendix D, Table D-3, and Appendix B)

Step 1. Determine the probable distribution of the subject waste stream among disposal types based on readily available information.

Compile all relevant estimates from each reference source above. Most of the data in these surveys may pertain specifically to hazardous waste; in the absence of better information, assume that nonhazardous waste is treated similarly. List all available estimates and decide which to use based on how recent the information is, the reliability of the data collection methods, or other factors. If appropriate, estimates from different sources can be combined and averaged.

Step 2. Determine whether it is likely that the subject waste stream is co-disposed with hazardous waste.

Co-disposal is likely when hazardous and nonhazardous wastes are generated simultaneously or in a manner likely to result in their mixing; it is then often not economically advantageous to separate them. This information may be deduced from information compiled in Stages I and II. If it appears likely that the waste will be diverted to a hazardous waste stream, conduct an HWDMS retrieval as described in Section 2.3.3(4) for hazardous waste (see Appendix D, Exhibit D-1).

Step 3. If data collected thus far are inadequate, skip ahead to Stage IV; information obtained there can be applied to Stage III. In any case, after Stage IV is completed, return to Stage III and make any necessary adjustments.

Step 4. If the Stage IV procedures do not provide the desired information, estimate the quantity of waste handled by each disposal practice based on the waste disposal practices of similar industries, or on the relative proportions of different types of disposal facilities available in the area (see Section 2.3.3(4) and Stage IV).

The output of this step will be a list of the disposal practices likely to be used for the subject waste and estimates of the amounts disposed by each practice in units of mass/year. The uncertainty in these estimates may be high as a result of the paucity of information on nonhazardous waste disposal practices.

(6) Municipal Solid Waste (MSW). This category includes all nonindustrial solid waste: residential, commercial/institutional, construction/demolition, and agricultural. General information on MSW is given in (a) followed by the Stage III decision tree in (b).

(a) Background information. The typical composition of MSW is given in Table 13. A description of various types of MSW follows:

- Residential (domestic). This includes all wastes generated by normal household activities, including food wastes, paper, clothing, and manufactured objects, as well as yard waste resulting from lawn and garden care. It also includes wastes from campgrounds, public access areas, and roadside rest stops. Toxic substances may enter these waste streams by means of household cleaning chemicals; paints; lawn and garden chemicals; and as components of manufactured products such as plastics, batteries, dyes in clothing, or paper. Nationwide, about 90 percent of residential waste is landfilled and the rest is incinerated (Lacombe 1977). Wastes are hauled by public or private haulers or transported by homeowners to municipal disposal sites.

- Commercial/institutional. These wastes are generated from a variety of sources, such as: shopping centers, restaurants, hotels, schools, hospitals, nursing homes, and automobile service stations. They also include street sweepings and refuse from litter baskets. Generators of commercial waste include the following employment groups: transportation, communications, and utilities; wholesale and retail trade; finance, insurance, and

Table 13. Composition and Analysis of an Average Municipal Refuse

			Analysis (percent dry weight)						
Component	Percent of all refuse by weight	Moisture (percent by weight)	Volatile matter	Carbon	Hydrogen	Oxygen	Nitrogen	Sulfur	Non-combustibles
Rubbish, 64%:									
Paper	42.0	10.2	84.6	43.4	5.8	44.3	0.3	0.20	6.0
Wood	2.4	20.0	84.9	50.5	6.0	42.4	0.2	0.05	1.0
Grass	4.0	65.0	...	43.3	6.0	41.7	2.2	0.05	6.8
Brush	1.5	40.0	...	42.5	5.9	41.2	2.0	0.05	8.3
Greens	1.5	62.0	70.3	40.3	5.6	39.0	2.0	0.05	13.0
Leaves	5.0	50.0	...	40.5	6.0	45.1	0.2	0.05	8.2
Leather	0.3	10.0	76.2	60.0	8.0	11.5	10.0	0.40	10.1
Rubber	0.6	1.2	85.0	77.7	10.4	...	...	2.0	10.0
Plastic	0.7	2.0	...	60.0	7.2	22.6	...	...	10.2
Oils, paints	0.8	0.0	...	66.9	9.7	5.2	2.0	...	16.3
Linoleum	0.1	2.1	65.8	48.1	5.3	18.7	0.1	0.40	27.4
Rags	0.6	10.0	93.6	55.0	6.6	31.2	4.6	0.13	2.5
Street sweepings	3.0	20.0	67.4	34.7	4.8	35.2	0.1	0.20	25.0
Dirt	1.0	3.2	21.2	20.6	2.6	4.0	0.5	0.01	72.3
Unclassified	0.5	4.0	...	16.6	2.5	18.4	0.05	0.05	62.5
Food wastes, 12%:									
Garbage	10.0	72.0	53.3	45.0	6.4	28.8	3.3	0.52	16.0
Fats	2.0	0.0	...	76.7	12.1	11.2	0.0	0.00	0.0
Noncombustibles, 24%:									
Metals	8.0	3.0	0.5	0.8	0.04	0.2	...	...	99.0
Glass & ceramics	6.0	2.0	0.4	0.6	0.03	0.1	...	...	99.3
Ashes	10.0	10.0	3.0	28.0	0.5	0.8	...	0.5	70.2
Composite refuse, as received:									
All refuse	100	20.7	...	28.0	3.5	22.4	0.33	0.16	24.9

Source: USEPA 1983b.

real estate; and services, schools, and hospitals. These wastes are similar to residential wastes and are treated the same way, although commercial generators probably use a larger proportion of private haulers and private disposal sites. U.S. households and commercial sources together generate more than 140 million tons of solid waste annually (USEPA 1977).

- Demolition/construction. Waste types include bricks, soil, rock, concrete, and pipes, as well as brush and wood waste. Most of this is used on-site as clean fill or in construction such as for service roads. The rest is landfilled at municipal or industrial landfills. Special demolition landfills are rarely used. Construction waste generation is seasonal, in keeping with the nature of the industry. The category also includes materials disposed of in "disaster" landfills, selected on a case-by-case basis at the time of a particular disaster. These are used only once and covered over. Toxic waste components include preserved wood, asphaltic materials, and asbestos.

- Agricultural. This includes wastes generated from raising and harvesting animals, grains, fruits and vegetables, and other field crops. It excludes food processing wastes, which are commercial. The large majority of agricultural waste is returned to the land on the farmsite. Manure and other livestock solid wastes from feedlot and dairy operations are normally collected and stockpiled on-site until they can be spread on and disked into adjacent acreage. Most crop residues are shredded or chopped and disked or plowed back into the topsoil. Some crop residues are removed for burning and composting. The rest are probably landfilled. Toxic components include pesticides and fertilizers and their containers.

The disposal practices for MSW are summarized in Table 14. Nationwide, 90 percent is landfilled and most of the balance is incinerated.

Table 14. Municipal Solid Waste: Disposal Practices

Landfill
Incineration
Recycling
Landspreading

The only other options in use are resource recovery and landspreading. The extent of resource recovery varies widely from one area to another. For a given location, the extent of resource recovery of MSW can be estimated by examining the latest resource recovery survey in Waste Age Magazine (see Table I-1 in Appendix I), which gives the locations and capacities of all resource recovery installations in the U.S. Nationally, no more than 6 percent of all waste is recycled (City of Kalamazoo 1978). Landspreading of shredded municipal refuse is insignificant nationally but may be the most important disposal practice for a given city, as in Odessa, Texas (Phung et al. 1977, 1978).

Average MSW generation per capita in the U.S. is currently 2.3 kg/day and increasing. By 1990, 157 million metric tons will be generated per year, of which 16 million metric tons will be incinerated and 141 million metric tons landfilled (Gordon 1979). If effective resource recovery programs are implemented nationwide, at least as much waste from domestic and commercial sources will be landfilled and incinerated as today. If the rate of recycling does not increase, the amount of MSW going to landfills will increase by 15 percent (Gordon 1979).

(b) Stage III decision tree for MSW. The Stage III estimates for MSW are simple and more accurate than parallel estimates for other waste categories, because the MSW disposal options are limited. For the most part, the user can assume that MSW is landfilled unless there is information to the contrary (e.g., the city of interest has a municipal incinerator).

Step 1. For assessments of broad geographic scope that do not require site-specific data, assume that 90 percent of MSW is landfilled and 10 percent incinerated; then proceed directly to Stage IV. If site-specific data are required, proceed to Step 2 below.

Step 2. Estimate the total MSW generated in the subject area based on per capita estimates (see Section 3, Table 18) and census data; this may be considered equivalent to the quantity disposed of in that area.

Step. 3. Estimate the quantity of MSW incinerated in the subject area.

Consult the inventories of municipal incinerators (Appendix I, Tables I-2 and I-3) to see if any such facilities are located in the subject area. If so, list these facilities and their capacities.

Step 4. **Estimate the quantity of MSW recycled in the subject area.**

Consult the latest inventory of resource recovery operations in Waste Age magazine (Appendix I, Table I-1) to see if any such facilities are located in the study area. If so, list these facilities and their capacities.

Step 5. **Estimate the quantity of MSW shredded and landspread in the subject area.**

Landspreading of shredded MSW is an uncommon practice that can be ignored when considering broad geographic areas; however, it may be the major practice used for MSW disposal in a given city. Contact the applicable state solid waste agency for information on the subject site.

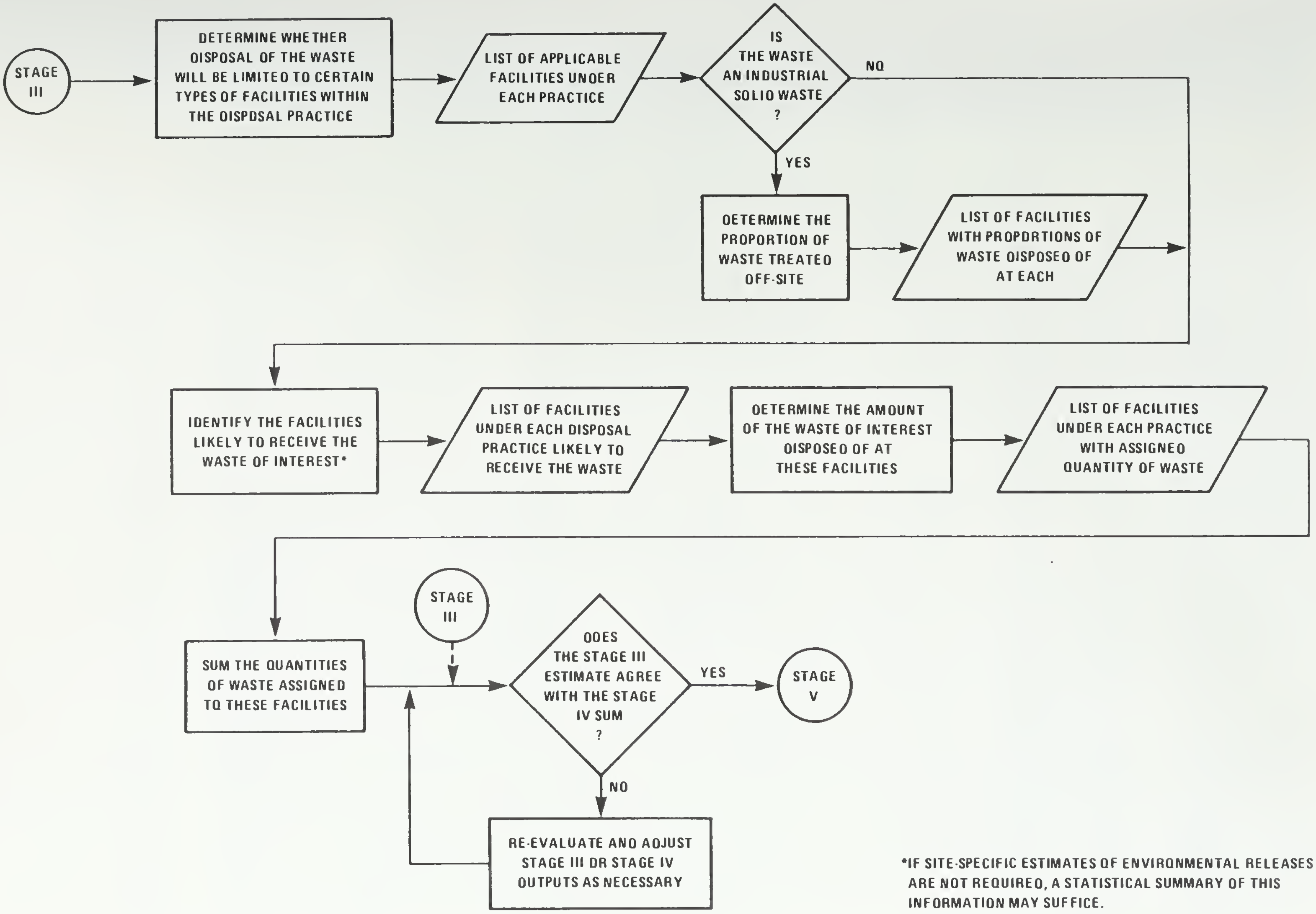
Step 6. **Estimate the quantity of MSW disposed of in landfills in the subject area, based on estimates generated in Steps 2 through 5 above.**

The quantity landfilled equals the total quantity generated minus the quantities incinerated, recycled, and landspread.

2.3.4 Stage IV Decision Tree - Allocating Waste Streams to Individual Disposal Sites

A flow chart summarizing the procedures in Stage IV is presented in Figure 6. This stage of the framework involves estimating the amount of a waste stream disposed of at each site by each disposal practice. The input for this stage is the estimate, from Stage III, of the quantity of the subject waste disposed of by each practice. However, if this estimate was not based on site-specific data, then it should be used for Stage IV calculations only if no better estimates are available. As stated in the preamble to Stage III (Section 2.3.3), if site-specific information is available for Stage IV estimates, the output from Stage IV can be used to correct the preliminary output from Stage III. Stage IV (and Stage V) will be performed once for each disposal practice used for a given waste stream. Because the exact format and supporting information from Stage IV will be different for each disposal practice, the following decision tree should be used only as a guide to the format of the decision trees tailored to each disposal practice. (Stage IV decision trees adapted respectively to landfills, land treatment, surface impoundments, POTWs, incinerators, and injection wells are presented in Section 3 through 8).

The degree of detail desirable in the Stage IV output depends on the level of detail required for the modeling of environmental releases in Stage V. Even for non-site-specific exposure assessments, the facility "population" data obtained in Stage IV (i.e., number of facilities and their capacities) may be required to develop a statistical profile for extrapolating nationwide exposure from a select number of representative disposal facilities. (See Volume 1 of this series for an explanation of this approach.)


STAGE III
DETERMINE WHETHER DISPOSAL OF THE WASTE WILL BE LIMITED TO CERTAIN TYPES OF FACILITIES WITHIN THE DISPOSAL PRACTICE
LIST OF APPLICABLE FACILITIES UNDER EACH PRACTICE
IS THE WASTE AN INDUSTRIAL SOLID WASTE ?
NO
YES
DETERMINE THE PROPORTION OF WASTE TREATED OFF-SITE
LIST OF FACILITIES WITH PROPORTIONS OF WASTE DISPOSED OF AT EACH
IDENTIFY THE FACILITIES LIKELY TO RECEIVE THE WASTE OF INTEREST*
LIST OF FACILITIES UNDER EACH DISPOSAL PRACTICE LIKELY TO RECEIVE THE WASTE
DETERMINE THE AMOUNT OF THE WASTE OF INTEREST DISPOSED OF AT THESE FACILITIES
LIST OF FACILITIES UNDER EACH PRACTICE WITH ASSIGNED QUANTITY OF WASTE
SUM THE QUANTITIES OF WASTE ASSIGNED TO THESE FACILITIES
STAGE III
DOES THE STAGE III ESTIMATE AGREE WITH THE STAGE IV SUM ?
YES
STAGE V
NO
RE-EVALUATE AND ADJUST STAGE III OR STAGE IV OUTPUTS AS NECESSARY

*IF SITE-SPECIFIC ESTIMATES OF ENVIRONMENTAL RELEASES ARE NOT REQUIRED, A STATISTICAL SUMMARY OF THIS INFORMATION MAY SUFFICE.

FIGURE 6. SUMMARY OF STAGE IV: ALLOCATION OF WASTE STREAMS TO INDIVIDUAL DISPOSAL SITES

Step 1. Determine whether disposal of the subject waste is limited to certain subtypes of the disposal practice under consideration.

Consider the type and source of the waste stream and the legal and practical constraints on the subject disposal method. List the applicable subtypes and proceed to Step 2.

Step 2. If applicable, determine the proportional distribution of the subject waste between on-site and off-site facilities.

This information will be useful in determining which individual sites are likely to handle the waste (Step 3). Consider the following in the absence of information to the contrary.

- Residential/commercial waste. If the waste derives from consumer use, assume that it is disposed of off-site with MSW unless it is discharged through the sewer system to POTWs.

- Industrial waste. If the waste derives from industrial operations, determine what percentage is disposed of with MSW, what percentage is disposed of off-site by private waste disposal businesses, and what percentage is disposed of on-site. Take into account whether the waste is a hazardous waste, and use available information on waste disposal practices. No generic data in support of this decision are currently available for nonhazardous industrial waste.

- Wastewater. By definition, all domestic wastewaters routed to POTWs are disposed of off-site. The percentage of industrial wastewaters discharged indirectly (off-site) will have been determined in Stage III.

Step 3. Identify the individual facilities using the subject disposal practice that are probable candidates for disposal of the subject waste stream, based on information derived from Steps 1 and 2 and available inventories of facilities.

The output of this step for a detailed exposure assessment will be a list of the sites and their locations. An estimate of the total number of facilities in the population may suffice for nationwide or regional exposure assessments that do not require site-specific modeling of environmental releases.

Step 4. Ascertain whether information exists on the capacity and current operating characteristics for the sites listed in Step 3. Use this information along with available information on the disposal practices of the source of the subject waste to estimate the amount of the waste stream disposed of at each facility.

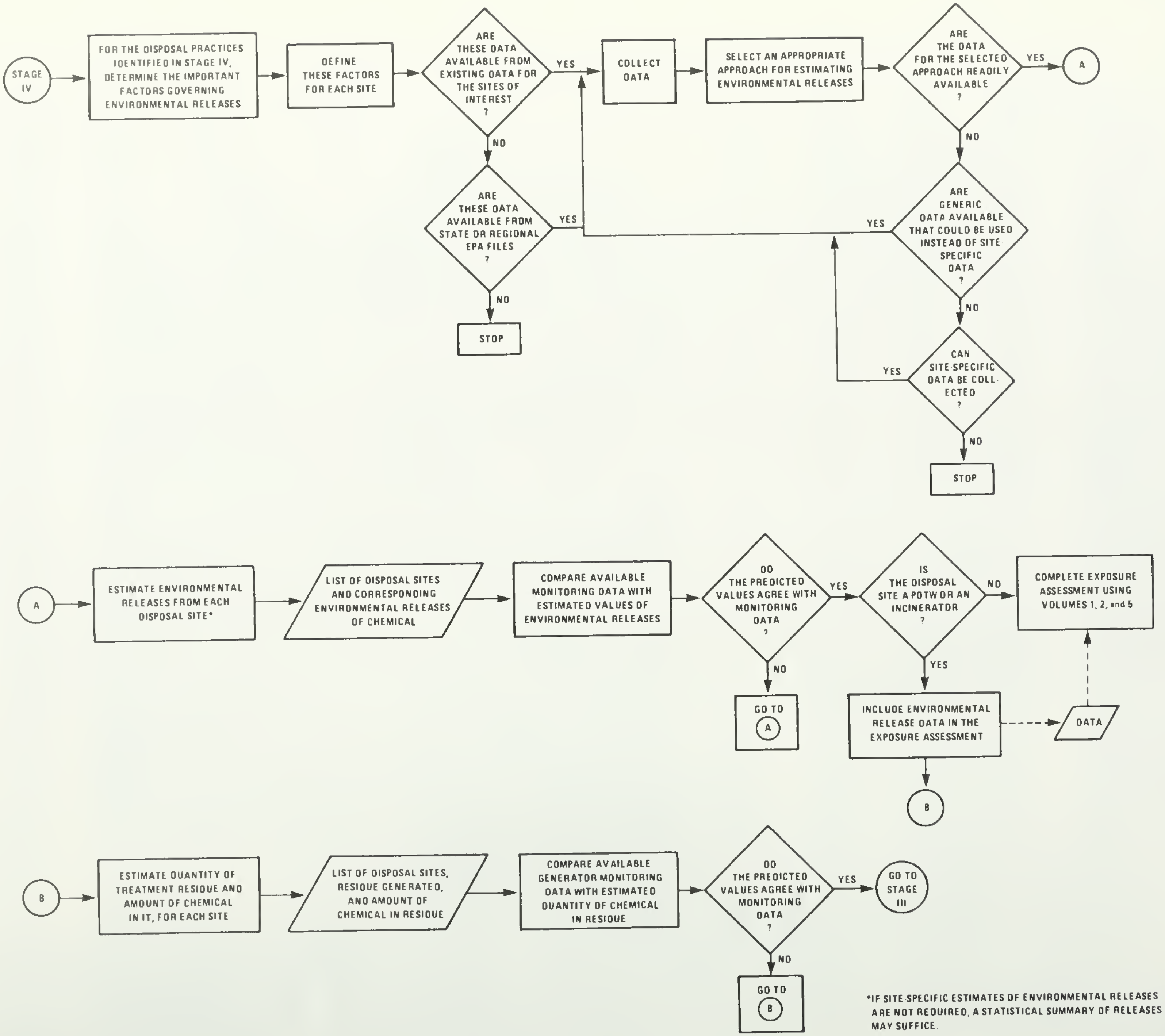
The output of Stage IV for exposure assessments requiring site-specific estimates of environmental releases will be a list of candidate sites and the quantity of the subject waste stream disposed of at each site. For exposure assessments that do not require site-specific modeling, the output may be as simple as the number of facilities and the average quantity of the waste handled per facility, or as complex as a statistical distribution of the population of facilities by waste quantity handled.

2.3.5 Stage V Decision Tree - Estimating Environmental Releases from Disposal Sites

A flow chart showing the Stage V procedures is presented in Figure 7. This stage involves estimating releases to the environment from disposal, given the Stage IV estimates of the amount of waste handled at each disposal facility. For maximum accuracy in exposure assessments, Stage V release estimates should be made for each disposal facility. In nationwide exposure assessments, however, it may be impractical to model releases from each site. This would be the case, for example, where exposure from a substance disposed of in all municipal landfills is being investigated. In these assessments, releases can be estimated from model environments representing the range of "typical" disposal facilities and extrapolated in a statistically acceptable fashion to a national scale. See Volume 1 of this series for a discussion of this and other planning issues.

Obviously, the information compiled in Stage II on the physical/chemical characteristics of the waste will be essential in this stage because releases are partially determined by characteristics of the waste containing the subject chemical. The following general decision tree is a guide to the format of the decision trees for each disposal/treatment practice. (Stage V decision trees tailored to landfills, land treatment, surface impoundments, POTWs, incinerators, and injection wells are presented in Sections 3 through 8.)

Step 1. a. Identify the important design and operating characteristics of the waste disposal method that affect releases to the environment.


STAGE IV
FOR THE DISPOSAL PRACTICES IDENTIFIED IN STAGE IV, DETERMINE THE IMPORTANT FACTORS GOVERNING ENVIRONMENTAL RELEASES
DEFINE THESE FACTORS FOR EACH SITE
ARE THESE DATA AVAILABLE FROM EXISTING DATA FOR THE SITES OF INTEREST ?
YES
NO
ARE THESE DATA AVAILABLE FROM STATE OR REGIONAL EPA FILES ?
YES
NO
STOP
COLLECT DATA
SELECT AN APPROPRIATE APPROACH FOR ESTIMATING ENVIRONMENTAL RELEASES
ARE THE DATA FOR THE SELECTED APPROACH READILY AVAILABLE ?
YES
A
NO
ARE GENERIC DATA AVAILABLE THAT COULD BE USED INSTEAD OF SITE-SPECIFIC DATA ?
YES
NO
CAN SITE-SPECIFIC DATA BE COLLECTED ?
YES
NO
STOP
A
ESTIMATE ENVIRONMENTAL RELEASES FROM EACH DISPOSAL SITE*
LIST OF DISPOSAL SITES AND CORRESPONDING ENVIRONMENTAL RELEASES OF CHEMICAL
COMPARE AVAILABLE MONITORING DATA WITH ESTIMATED VALUES OF ENVIRONMENTAL RELEASES
DO THE PREDICTED VALUES AGREE WITH MONITORING DATA ?
YES
NO
GO TO A
IS THE DISPOSAL SITE A POTW OR AN INCINERATOR ?
NO
YES
COMPLETE EXPOSURE ASSESSMENT USING VOLUMES 1, 2, and 5
INCLUDE ENVIRONMENTAL RELEASE DATA IN THE EXPOSURE ASSESSMENT
DATA
B
B
ESTIMATE QUANTITY OF TREATMENT RESIDUE AND AMOUNT OF CHEMICAL IN IT, FOR EACH SITE
LIST OF DISPOSAL SITES, RESIDUE GENERATED, AND AMOUNT OF CHEMICAL IN RESIDUE
COMPARE AVAILABLE GENERATOR MONITORING DATA WITH ESTIMATED QUANTITY OF CHEMICAL IN RESIDUE
DO THE PREDICTED VALUES AGREE WITH MONITORING DATA ?
YES
GO TO STAGE III
NO
GO TO B

*IF SITE-SPECIFIC ESTIMATES OF ENVIRONMENTAL RELEASES ARE NOT REQUIRED, A STATISTICAL SUMMARY OF RELEASES MAY SUFFICE.

FIGURE 7. SUMMARY OF STAGE V – ESTIMATING ENVIRONMENTAL RELEASES FROM DISPOSAL SITES

b. Ascertain which of the parameters listed in 1.a are known for the site(s) of interest based on accessible computerized data or other in-house information.

c. Identify which of the parameters listed in 1.a but not 1.b can probably be obtained from existing files at regional EPA office(s) and/or state solid waste agencies.

Step 2. a. Identify the available approaches for predicting environmental releases based on design/operating characteristics. If no approaches are available, then releases cannot be estimated. Otherwise, choose the appropriate approach and go to 2.b.

b. Determine what site-specific design/operating characteristics are required for input to the predictive approach chosen in 2.a. Decide whether these are readily available (see 1.b). If not, determine whether there are "surrogate" values that can be used in place of the site-specific parameters. If there are no suitable input data available, two options exist: (1) collect data listed in 1.c or collect new data; (2) abandon the predictive effort. If input data are available, go to 3.

Step 3. Using the chosen predictive method and input data, estimate releases of the subject chemical from each disposal site receiving the subject waste. Alternatively, estimate releases from one or more representative sites (actual or hypothetical) and extrapolate these releases to a regional or national scale (see Volume 1 of this series). Consider using the inventory compiled in Stage IV as a basis for this extrapolation.

The output of this step should include estimates not only of ultimate releases to environmental media, but also subject chemical mass/concentration in any residues that may result from the treatment/disposal practice. (Such residues include incinerator ash and POTW sludge).

Step 4. If monitoring data are available, compare with values estimated in Step 3. If estimated releases and chemical quantities in residues (if any) do not correlate with measured values, use best judgment to evaluate the discrepancy. If applicable, calibrate the model and rerun. Information on the subject chemical in treatment residues should be used as input to Stage III for an analysis of ultimate releases from the residue. Then use the estimated releases as input in the analysis of environmental fate and pathways of the final exposure assessment (see Volumes 1, 2, and 5 of this report).

3. LANDFILLS

This section discusses the information needed to estimate the potential for environmental releases of chemicals from landfills, and focuses on municipal, industrial, and hazardous waste landfills. Landfills are of particular interest because they are a major collective repository of wastes and have the potential to release toxic chemicals to air and water. General background material about landfill types and operation is given in Section 3.1. Decision trees based on this information are presented for Stage IV in Section 3.2, and for Stage V in Section 3.3. There are major gaps in the state-of-the-art knowledge on the behavior of chemical substances in landfilled wastes, which may seriously limit the ability to estimate releases from landfills. On the other hand, there is a considerable body of knowledge on the types and amounts of wastes that are landfilled, as well as on landfill sizes, capacities, and operating characteristics, which will be useful in exposure assessments.

3.1 Background Information

This section presents some information on landfills that will be useful in conducting both site-specific and large-scale exposure assessments. Included for discussion are (1) the difficulties caused by having only very general information on some types of landfills, (2) the current state of the art in estimating environmental releases from landfills, and (3) methods for estimating some site-specific input parameters likely to be useful in modeling these releases. Some modeling-related considerations and ideas on using the available information in large-scale assessments are also discussed.

3.1.1 Landfill Types and Operation

There are five types of landfills:

- Municipal landfills. These primarily handle municipal waste and may be privately or publicly owned and operated. Municipal landfills may also accept other types of waste, such as nonhazardous industrial, construction, and agricultural waste. There are an estimated 12,000 to 15,000 active municipal landfills in the U.S. (Petersen 1983, USEPA 1980f).

- Industrial landfills. About 23 percent of all industrial plants landfill on-site; there are presently about 76,000 on-site industrial landfills (USEPA 1980f). Industrial nonhazardous waste disposed of off-site may also be handled at a municipal site. Since most off-site landfills handle a variety of waste types, no distinction will be drawn in this report between municipal and industrial (nonhazardous) off-site landfills.

- Hazardous waste landfills. These differ from industrial nonhazardous landfills by having to meet more stringent permitting, design, and operational criteria. There are about 500 on-site and 44 off-site hazardous waste landfills in the U.S. (Table 21 in Section 3.1.5; Table D-7 in Appendix D).

- Construction landfills. Most construction/demolition waste is disposed of in municipal landfills. Only a few landfills specialize in construction waste.

- Agricultural landfills. Agricultural waste not returned to the soil is usually taken to municipal landfills. No information is available on strictly agricultural landfills.

Construction and agricultural landfills will not be considered further in this report because they are not expected to be major repositories for toxic substances subject to regulation (except for asbestos from construction wastes); moreover, very little information is available on these sites.

The three most common operational practices for landfills are the area, ramp, and trench methods (Anon. 1981b). In the area method, wastes are spread onto the existing ground surface, compacted, and covered with earth from another source. This method is useful with depressions that are to be filled as a landfill, or in building earthen structures above the surface of the existing ground. The ramp (or progressive slope) method is a variation of the area method. Here the earth cover is excavated from the ground immediately in front of the active working face. In the trench method, a trench is excavated and wastes are placed in the trench, compacted, and covered with soil. The excavated earth can either be used to cover the solid wastes in an adjacent trench or stockpiled to cover the wastes in the trench being excavated. The volume of waste covered with earth during each day's operation is referred to as a cell or lift.

The trench method is the most common method used and is required by some state regulations. Current use of the area and ramp methods is not common. Calculations in this report will be based on the assumption that all landfills use the trench method.

3.1.2 Environmental Releases from Landfills

(1) Leachate. Pollutant leachate is generated when water enters the landfill, migrates through it, and picks up soluble materials from the disposed waste, either original waste compounds or the soluble products of biological and chemical degradation. Water can enter a landfill as precipitation, surface runoff, or infiltration of groundwater (Patel et al. 1979).

Generation of leachate does not necessarily begin with the first addition of water. Solid wastes act like a sponge and are capable of storing about 135 to 270 ℓ/m^3 of material (1 to 2 gal/ft^3) (Anon. 1981b). Leachate will be generated only after this storage capacity (field capacity) is reached and more water is added. (In practice, channels may form within the waste which allow the water to flow through more quickly.) The time required for leachate generation is highly variable and depends on local in situ conditions and rainfall (Anon. 1981a).

Pollutant leachate may reach both groundwater and surface water, and many examples of leachate pollution have resulted in the contamination of water supplies or the habitats of aquatic life (CEQ 1981). The composition of leachate is variable, because it is highly waste- and site-specific. The chemical complexity of municipal solid waste (MSW) leachate is illustrated in Table 15. Leachate from hazardous waste is even more waste-specific; no general figures can be compiled in a meaningful manner. Leachate may react chemically with landfill lining materials. Depending on the nature and concentration of constituents in the leachate and the nature of the lining materials, leachate may damage or cause failure of the liner.

(2) Gases and dusts. Some of the decomposition products resulting from the microbial degradation of solid waste are in gaseous form. Although such degradation produces a variety of gases, methane and carbon dioxide are the major gaseous products of landfill decomposition. Migration of gas produced in a landfill may lead to a number of environmental effects, ranging from odor problems to the accumulation and explosion of methane (Patel et al. 1979). Theoretically, about 0.2 m^3 of methane gas can be produced from each pound of waste (Anon. 1981b).

In addition to gaseous decomposition products, organic compounds in landfilled wastes may volatilize and migrate from the soil to the atmosphere. The continuous emission of these organic compounds, if they include toxic materials, may cause significant harm to public health and the environment. Volatilization is a function of temperature, wind speed, surface area, depth of buried waste, and waste characteristics. Because the volatilization and degradation processes may be slow, the emission of hazardous volatile organic compounds may persist for many years. Gas generation rates at landfills have not been well studied, and the extent of air contamination from these sites is largely unknown (Shen 1981).

Landfills that are poorly designed and operated may also emit dusts containing chemical substances.

Table 15. Characteristics of MSW Leachates Reported in Five Studies[a]
(All values in mg/l)

Component	I	II	III	IV	V[b]	
	Range	Range	Range	Range	Fresh	Old
BOD_5	9-54,610	...	7,500-10,000	...	14,950	...
COD	0-89,520	100-51,000	16,000-22,000	500-1,000	22,650	81
Total dissolved solids	0-42,276	...	10,000-14,000	...	12,620	1,144
Total suspended solids	6-2,685	...	100-700	...	327	266
Total nitrogen	0-1,416	20-500	...	...	989	7.51
pH	3.7-8.5	4.0-8.5	5.2-6.4	6.3-7.0	5.2	7.3
Electrical conductivity (μmho/cm)	...	...	6,000-9,000	1,200-3,700	9,200	1,400
Total alkalinity as $CaCO_3$	0-20,850	...	800,4,000	630-1,730	...	...
Total hardness as $CaCO_3$	0-20,800	200-5,250	3,500-5,000	390-800	...	...
Chemicals and metals:						
Cadmium (Cd)	...	...	0.4	...	...	...
Calcium (Ca)	5-4,080	...	900-1,700	111-245	2,136	254
Chloride (Cl)	34-2,800	100,2,400	600-800	100-400	742	197
Copper (Cu)	0-9.9	...	0.5	<0.04-0.11	0.5	0.1
Iron (Fe)	0.2-5,500	200-1,700	210-325	20-60	500	1.5
Lead (Pb)	0-5.0	...	1.6	...	...	...
Magnesium (Mg)	16.5-15,600	...	160-250	22-62	277	81
Manganese (Mn)	0.6-1,400	...	75-125	1.02-1.25	49	...
Phosphate (P)	0-154	5-130	...	21-46	7.35	4.96
Potassium (K)	2.8-3,770	...	295-310	107-242	...	...
Sodium (Na)	0-7,700	100-3,800	450-500	106-357	...	...
Sulfate (SO_4)	1-1,826	25-500	400-650	13-84	...	...
Zinc (Zn)	0-1,000	1-135	10-30	<0.04-0.47	45	0.16

[a] These studies did not analyze organic compounds.

[b] In this study the characteristics of fresh versus old leachate were compared.

Source: USEPA 1983b.

3.1.3 Predicting Environmental Releases

Much of what is discussed in this section about groundwater models is equally applicable to surface impoundments (Section 5), modeling releases from land treatment (Section 4), and deep well injection (Section 8). To avoid repetition, only salient points will be further discussed in Sections 4, 5, and 8. All models discussed in this section are included in Appendix A. The reader is also advised to see the companion volume on assessing exposures from drinking water (Volume 5 of this methods development series), since it contains a more detailed discussion of groundwater modeling.

Environmental releases from waste disposal sites may be predicted by the use of models. In general, the models are composed of concise mathematical expressions that use a series of equations to express relationships among various physical and chemical parameters in the waste disposal system. Depending on the method of analysis and the accuracy required, these models may range in structure from a few simple algebraic equations solved manually to hundreds of complex differential expressions which must be solved through the use of computers. An important consideration when deciding whether to use models is the level of data needed. Often the amount of information required by the model will exceed that which is available for site-specific assessments. In this case, a great deal of time and money may be required to allow for accurate model output.

Although the development and use of models for hazardous waste predictions have only recently received much attention, there are many models available to the investigator. A recent report (Weston 1978) provides a compilation of the different types of models available for possible use in groundwater evaluation studies. The U.S. EPA Office of Solid Waste (OSW) (USEPA 1982a) reviewed approximately 400 models and selected those which may be of most use for their risk analysis requirements; some of these are mentioned below. However, even those selected by OSW have limited capabilities; because of the numerous factors affecting chemical fate at disposal sites, no single model is capable of accounting for all variables. For this reason, most models do not attempt to predict all aspects of a chemical's fate; they are usually more specific in their objective.

Some general classifications for which several models are available to choose from for particular modeling scenarios are: watershed simulation models, release rate models, and solute transport models, which are further divided into unsaturated zone and saturated zone models.

The watershed simulation models have to be operated after each storm event to produce long-term simulations. Despite this, the results of long-term simulations tend to be more accurate than those for short-term simulations. An example of a useful model in this category is PRZM (Pesticide Root Zone Model, developed by the EPA Office of Research and Development), designed to model the transport of pesticides applied to soils. Unfortunately, it does not take into account the complexities involved in modeling landfills (i.e., the relation between landfill structure, liners, and pollutant transport), and thus it is of limited use.

Release rate models permit estimation of the quality and quantity of leachate released from a site. Output from the release rate model is used as input for one of the solute transport models. There are at least six release rate models documented in the literature (USEPA 1982a); several others are under development by various researchers. One of these models, called HELP (Hydrologic Evaluation of Landfill Performance) (Perrier and Gibson 1980), was developed specifically to evaluate hazardous waste landfills. The program was developed by the U.S. Army Corps of Engineers, Waterways Experiment Station, and allows rapid estimation of the amounts of runoff, subsurface drainage, and leachate that can be expected from different landfill designs and local climatic conditions. The program requires site-specific climatologic, soil, and landfill design data (including specifications for multi-layer and lined systems); default values can be assigned if these data are not available (except design data). Another potentially useful release rate model is one developed for the rapid assessment of groundwater contamination under emergency response conditions (Donigian et al. 1983). This approach makes use of easily-applied nomographs that are based on a transport-convection equation and requires input data similar to that needed for other models. This model accounts for contaminant transport as well as release, so that it includes features of some of the transport models described below. Additional models include Release Rate Computations, Post-Closure Liability Trust Fund (PCLTF), and DRAINMOD/DRAINFIL. More information on these models can be found in Volume 5 of this methods development series.

Solute transport models predict the dispersion of contaminants from the source. As mentioned above, they are capable of predicting chemical fate either in the unsaturated zone or in the saturated zone; the numerous hydrogeological differences between the two zones prevent them from being modeled together. Of the numerous transport models that have been developed, many are only for specific applications; however, several are more general in application and have been documented (USEPA 1982a) and field-verified. Most of these models solve a transport-convection equation in one, two, or three dimensions by a variety of methods (e.g., finite element methods, finite differences methods, or "random walk" methods). Three of the more familiar models currently in use are SESOIL, the Seasonal Soil Compartment Model (Bonazountas and Wagner 1981), AT123D, developed at Oak Ridge National Laboratory (Yeh 1981), and the Random Walk Solute Transport Model, developed by the Illinois State Water Survey (Prickett et al.1981). Other models are described in another reference (USEPA 1982a). SESOIL is of particular use because it is designed to be "user-friendly" and is contained within the EPA Office of Toxic Substances' Graphical Exposure Modeling System (GEMS). GEMS is a computer system that integrates environmental modeling functions to aid environmental analysts in performing exposure assessments. SESOIL is not currently tailored to estimating releases from landfills, however. Volume 5 of this series provides a practical model application involving SESOIL and AT123D.

Models also exist for estimating air emission alone (Hwang 1982, Shen 1981). Input parameters include soil porosity, moisture content, bulk density, cover thickness, molecular weight of the subject chemical, temperature, and landfill area.

3.1.4 Model Input Data

Depending on the type(s) of model(s) chosen to simulate the actual conditions at the site, the numbers and types of data required will vary. A brief discussion of parameters required for release rate and transport models is presented below, followed by recommended procedures for obtaining some of the most common input data.

Release rate models are generally divided into three necessary components, which respectively address leachate generation, constituent concentrations, and leachate release rates from the site. Definition of the primary factors affecting these components requires data such as precipitation characteristics (amount, duration, and frequency), water table elevation, evapotranspiration rate, solar radiation, temperature, humidity, soil profile, hydraulic conductivity, and pressure head. Measurements or design characteristics of the landfill are also required.

Transport models which rely on some method of solving a series of transport-convection equations require several physical and chemical parameters as input. These include void ratio, porosity, moisture content, hydraulic conductivity, dispersion-coefficients, infiltration, depth to groundwater, hydraulic gradient, aquifer thickness, boundary conditions (e.g., areal extent of aquifer, presence of recharge boundaries), and chemical characteristics of the contaminant (e.g., adsorption coefficients).

Recommended procedures for obtaining climatic, soil, chemical, and selected application-related geometric and application-specific data are presented below.

(1) Climatic data. For statistically related climatic input, parameters are compiled manually from climatological data sheets of the National Weather Service office of the National Oceanic and Atmospheric Administration (NOAA). NOAA reports provide daily, monthly, and annual summaries of climatological data for designated sites throughout the U.S. Input parameters can also be compiled with the aid of a user-supplied computer program, using the climatological data from NOAA which is recorded on magnetic tape.

(2) Soil data. Required soil parameters can be derived from soil maps and information prepared by the Soil Conservation Service (SCS), U.S. Department of Agriculture. Information is available on the soil types of many (but not all) areas of the U.S., identifying characteristics of the soil profile to a depth of 1.5 m (five feet). The SCS also prepares soil survey interpretation sheets by soil series; these tabulate significant soil engineering properties, including classification, permeability, water capacity, and pH for each major soil horizon. They also provide depth to water table and to bedrock (if less than 1.5 m), hydrologic group, suitability for various purposes, and nature and degree of limitation for certain uses including sewage lagoons and sanitary landfills. Some models have the capability of assigning default values in the event site-specific data cannot be found, e.g., for typical soil categories and their associated parameters. These data can be used as surrogate data when releases are being calculated for a broad geographical area or when site-specific data are unavailable. Table 16 provides some examples of the surrogate soil data compiled for the SESOIL model.

(3) Chemical data. Basic chemical parameters for the contaminants of interest can be obtained from standard reference manuals and/or estimation techniques.

(4) Application-related geometric and application-specific data. These data comprise a set of waste application-related geometric parameters (e.g., area of disposal site, depth to groundwater), and numerous application-specific parameters (e.g., pollutant loading, soil moisture). These data are sometimes available through the applicable state solid waste agency, at least for permitted sites. However, the printed inventories of disposal sites distributed by most states (see Section 2.3.3) rarely contain this information; it must be obtained through a personal visit to the state agency and a manual search of their files. An exception is California, which has a computerized data retrieval system (see Appendix B).

The following discussion proposes methods for obtaining generic data for non-site-specific applications; it will also propose methods for

Table 16. Precompiled Soil Parameters, SESOIL Data File

	Parameters				
Soil type	Soil density	Intrinsic permeability	Pore connectivity index	Porosity	% Organic carbon
	(g/cm^3)	(cm^2)	(-)	(-)	(%)
Clay	1.32	1.0×10^{-10}	12.0	0.45	1.46
Clay-loam	1.32	2.8×10^{-10}	10.0	0.35	1.32
Silty-loam	1.32	1.2×10^{-9}	6.0	0.35	3.00
Sandy-loam	1.32	2.5×10^{-9}	4.0	0.25	0.50

Source: Bonazountas et al. 1981.

estimating average parameters for broad geographic regions. The actual numerical estimates made here may be refined or replaced as the user becomes familiar with the methodology and as new sources of data become available.

Assumptions and estimates are based on information obtained from three EPA publications (USEPA 1979b, 1980b, 1980f) as well as from the periodic updates of the Waste Age Survey (WAS). The survey has been conducted on a more or less annual basis since 1974 by the editors of Waste Age, a trade journal of the solid waste disposal industry. The survey contains information on number, size, and classification of municipal landfills as well as other variables. Unfortunately, the recent surveys have been less comprehensive than the ones for previous years. The 1983 survey gives only the number of landfills, the number of sites with liners or monitoring wells, and the type of site ownership (see Table 17). It also includes some of the results of the 1981 and 1982 surveys for comparison. The 1981 survey, although comprehensive in scope, was incomplete, with fewer than half the states supplying data for some of the most important data categories. Selected useful data from the 1981 WAS appears in Table E-2 in Appendix E.

Each of the application-related parameters developed in this method is discussed below; useful landfill size and capacity estimates are summarized in Table 18.

(a) Depth to groundwater. Depth to groundwater is one of the important input parameters that is not readily available on a site-specific basis, except by a manual search of the facility files of the applicable state agency. Moreover, groundwater depth shows extreme variation from one region to another and cannot be calculated from other types of data. The groundwater depth parameter affects soil-moisture distribution in the soil column and, consequently, pollutant fate (transport and transformation). An approach for estimating groundwater elevations when site-specific data are not available is given below.

The U.S. Geological Survey (USGS) maintains a number of computerized data bases that contain water table levels on a site-specific basis, based on latitude/longitude. One data base, the Ground Water Site Inventory (GWSI), contains data from all 50 States and U.S. Territories. The quality and quantity of data, however, vary markedly from state to state. In addition to the nationwide data base, at least fourteen other similar data bases contain data on one or more states (see Appendix F, Table F-1, for a summary of these data bases). It is recommended that the USGS state geologist or USGS district groundwater expert be contacted when these data are required in the course of exposure analyses. A current list of USGS state geologists is given in Table F-2, Appendix F.

Table 17. Selected Data from the 1983 *Waste Age* Survey

	No. of landfills in state	No. of open dumps	No. to be upgraded	No. of permits for new sites	No. of sites with artificial liners	No. of sites with monitoring wells
Alabama	135	12	11	2	0	110
Alaska	NA*	NA	NA	NA	NA	NA
Arizona	116	28	27	3	0	7
Arkansas	311	78	NA	12	0	0
California	542	40	31	6	0	NA
Colorado	206	32	26	NA	NA	NA
Connecticut	151	36	24	0	0	38
Delaware	35	4	4	0	1	6
Florida	248	55	17	15	8	192
Georgia	284	6	4	48	0	45
Hawaii	25	9	4	2	NA	NA
Idaho	132	42	20	11	0	8
Illinois	329	42	0	43	1	186
Indiana	348	191	2	14	0	44
Iowa	94	0	0	5	1	56
Kansas	224	1	0	27	0	NA
Kentucky	128	34	NA	17	0	7
Louisiana	532	532	95	NA	NA	NA
Maine	308	45	NA	NA	2	28
Maryland	47	0	0	2	1	47
Massachusetts	283	81	NA	2	NA	NA
Michigan	362	150	0	20	4	53
Minnesota	185	60	0	2	0	NA
Mississippi	253	133	10	19	0	4
Missouri	128	2	1	6	0	45
Montana	222	16	13	5	0	17
Nebraska	400	1	0	3	0	15
Nevada	99	52	10	4	0	4
New Hampshire	101	26	0	0	2	1
New Jersey	185	5	1	NA	NA	NA
New Mexico	231	0	0	NA	NA	NA
New York	525	56	38	NA	NA	NA
North Carolina	167	1	0	7	1	0
North Dakota	130	0	NA	NA	0	0
Ohio	318	54	NA	6	NA	50
Oklahoma	225	66	60	40	0	0
Oregon	226	28	3	11	1	16
Pennsylvania	925	94	75	3	15	190

Table 17. (continued)

	No. of landfills in state	No. of open dumps	No. to be up-graded	No. of permits for new sites	No. of sites artificial liners	No. of sites monitoring wells
Rhode Island	18	4	1	0	0	14
South Carolina	225	0	0	4	0	55
South Dakota	200	140	5	8	0	12
Tennessee	161	6	2	12	0	53
Texas	1075	11	8	26	0	58
Utah	296	26	8	6	0	1
Vermont	92	4	0	6	NA	NA
Virginia	209	50	34	52	0	47
Washington	136	36	18	NA	NA	NA
West Virginia	127	41	36	NA	NA	NA
Wisconsin	1085	66	10	7	0	195
Wyoming	0	0	0	38	0	5
Totals	12,991	2396	598	494	37	1609

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*NA means data not available.

Source: Petersen 1983.

Table 18. Landfill Size and Capacity Estimates[a]

Parameter	Metric[b]	English
Industrial solid waste density	1,000 kg/m^3	(62.4 lb/cu ft)
Municipal solid waste density[c]	593 kg/m^3	(37 lb/cu ft)
Landfill capacity (volume)	30,228 m^3/ha	(43,000 cu ft/acre)
Landfill capacity (mass)		
Industrial waste	29,900 Wkkg/ha	(13,334 tons/acre)
Municipal waste[c]	17,850 Wkkg/ha	(7,963 tons/acre)
Per capita waste generation[d]		
Rural	≥1 kg/day	(≥2 lb/day)
Urban	≤4.5 kg/day	(≤10 lb/day)
U.S. average	2.3 kg/day	(5 lb/day)
Average trench depth	10 m	(30 ft)

[a] Based on data and assumptions discussed in Section 3.1.4(4). See Table 19 for estimates specific to landfilling of municipal sludges.

[b] Wkkg = wet metric tons.

[c] Based on average in-place density of co-disposed municipal and industrial wastes.

[d] On the basis of a 365-day year.

Unless a site listed in these data bases is located close to the disposal facility of interest, it is advisable to compile the computerized water table data from several sites in the area of interest, using latitude/longitude or any other geographic information, such as county name. Determine the average groundwater depth.

Sometimes the computerized data bases do not provide data for the geographic area of interest; sometime the precise locations of disposal sites will not be known. Several alternative approaches are possible in these cases. One approach is to base assumptions on the known pattern of wetland and floodplain distribution (see Figure F-1 in Appendix F); one can at least determine whether the water table in a given region is relatively high or low, and select an arbitrary value or set of limiting values on that basis. Alternatively, water table levels typical of unlined surface impoundments in the area could be used (see Section 5.3). Another general source of information on groundwater is a publication by USGS (USDI 1963), but it does not always provide water table information for a given region.

When the locations of disposal sites are not known, one approach is to estimate the distribution of landfill sites based on population distributions for the subject area. Landfill acreage is not distributed evenly throughout a region, but is concentrated in areas of high population density. This is certainly true of municipal landfills, and to a lesser extent of industrial landfills, despite the increasing tendency for industry to develop in rural areas. After the relative proportions of landfill acreage in wet and dry zones is calculated, limiting values may be selected to represent the likely range of groundwater depths for each zone. Table E-1 in Appendix E provides estimates of population distribution with respect to wetlands.

(b) Depth of unsaturated soil zones. Depending on the model used, one or many separate unsaturated soil layers may be modeled. Landfill layers, covers, and liners may therefore constitute separate "soil" layers for the purposes of modeling. Simulations of landfills with impermeable clay liners or coarse solid wastes are possible with some of the models now available. The following are default estimates of depths of various discrete layers in landfills that may be useful in modeling:

- Average depth of fill material: 10 m (USEPA 1980f)
- Average depth of single cell: 2.5 m (USEPA 1980f)
- Depth of daily cover: 0.2 m; depth of final earth cover: 0.6 m (as prescribed by most state regulations).

(c) Pollutant loading. Pollutant quantities originating from the site may be input to the model in several ways, depending on the model selected. If the pollutant is assumed to be present as a concentrated mass, as in a landfill, a leaching rate from the waste must be specified. If the pollutant is already mixed into the soil, as in some landspreading operations, the total pollutant concentration present in the upper soil layer can be given.

Usually, it will not be possible to determine the leaching rate directly. Although a number of studies estimate leaching rates of various chemicals in soil (Roulier 1977, Wigh and Brunner 1979, Streng 1977, O'Donnell et al. 1977), few, if any, data are available on leaching rates of pollutants in the waste mass itself, which is highly chemical-specific. Until the state-of-the-art understanding of this process is more refined, leaching rates from the waste mass will have to be determined on a case-by-case basis. Unavailability of this information constitutes a major data gap.

(d) Area to be modeled. Assuming that the subject waste is disposed of throughout the year, the area to be modeled will be equivalent to the area of the landfill that is utilized annually. Landfill capacity and rate of fill information is rarely available except by manual search of state files. Estimates must be derived from whatever data are available on the basis of the assumptions discussed below. Estimates for landfill area are presumed to apply equally to municipal and industrial off-site landfills.

The 1981 Waste Age Survey (Anon. 1981c, see Table E-2 in Appendix E) divides landfills into six size categories according to capacity expressed in tons per day (tpd). Most (76 percent) fall into the smallest size category (0-50 tpd, or 0-45 metric tons per day). It can be assumed that these serve smaller populations in the rural areas, while larger facilities serve more urbanized regions. Some rural areas undoubtedly have initiated regional systems, in which case the solid wastes from these areas would be disposed of in a large capacity landfill; however, for calculation purposes, it will be assumed that rural landfills uniformly accept a maximum of 45 metric tons per day of waste each.

The area of an urban landfill can be estimated by consulting the Waste Age Survey for the relative size distributions of larger landfills within the subject state (see Table E-2 in Appendix E). In general, the total regional municipal landfill area should be proportional to the regional population distribution.

All on-site industrial (hazardous and nonhazardous) landfills may be assumed to fall into the smallest size category (0-45 metric tpd) (USEPA 1980f).

The above assumptions permit an estimate of the probable capacity of a given landfill; however, they do not directly satisfy the modeling input requirement of "area to be modeled." To achieve this, one must have an estimate of the waste capacity per unit landfill volume.

In general, four interrelated factors influence the amount of waste that can be disposed of per hectare. These are (USEPA 1980b):

- The overall size of the landfill. This defines how much area can be used for disposal and how much area must be used as buffer around the disposal area. The smaller the landfill, the greater the proportion of acreage which must be used as a buffer.
- The size of the trenches. A typical trench may have surface dimensions of 30 by 60 m and have an average depth of 10 m.
- The percentage utilization within a trench. The percentage of trench utilized for waste disposal depends on the materials being disposed of and the spacing practices of the operator.
- The density of the material. There is significant variability depending on the actual wastes being disposed of, discussed in detail below.

Industrial (hazardous and nonhazardous) waste is usually a liquid or sludge or a relatively dense, homogeneous solid. Therefore its density will be assumed to approximate the density of water, 1,000 kg/m^3 (62.4 lb/cu ft. or 8.34 lb/gal), a commonly accepted assumption in the disposal industry (USEPA 1980b).

Municipal waste is considerably less dense; even after compaction and mixing with co-disposed industrial waste, the average density of total mixed waste accepted by municipal landfills is estimated at 593 kg/m^3 (37 lb/cu ft) (USEPA 1979b).

The average capacity per acre of landfill is assumed to be 30,228 m^3/ha (16,000 cu yd/acre); this estimate has been confirmed by industry representatives (USEPA 1980b). On this basis, 29,900 wet kkg/ha, of industrial waste occupies one hectare, and 17,850 wet kkg of municipal waste occupies one hectare. See Table 19 for capacity estimates pertaining specifically to landfilling of municipal sludges.

Therefore, in the absence of site-specific information, the following equations can be used to determine the area of a given landfill utilized for waste disposal in one year. Note that the formula for industrial waste assumes that such waste is generated continuously. If the subject waste results from a batch manufacturing process, the necessary adjustments should be made to reflect the smaller volume occupied by the waste.

Table 19. Recommended Design Criteria for Disposal of Municipal Sludge in Landfills

Parameter	Area fill mound	Area fill layer	Diked containment
Sludge solids content	Greater than 20%	Greater than 15%	20 to 28% for land-based equipment; more than 28% for sludge-based equipment
Sludge characteristics	Stabilized	Stabilized	Stabilized or unstabilized
Ground slopes	No limitation if suitably prepared	Level ground preferred	Level ground or steep terrain if suitably prepared
Bulking required	Yes	Yes	Occasionally
Bulking ratio of soil to sludge	0.5 to 2 parts soil to 1 part sludge	0.25 to 1 part soil to 1 part sludge	0 to 0.5 part soil to 1 part sludge
Sludge application rate	6,000 to 26,000 m^3/ha	4,000 to 17,000 m^3/ha	9,000 to 28,000 m^3/ha

Source: USEPA 1980g.

For landfills accepting only industrial wastes:

$$\frac{\text{kkg/day} \times 260\ (\text{day/yr})^{*}}{29{,}900\ \text{kkg/ha}} = \text{hectares filled annually} \qquad (3\text{-}1)$$

For landfills accepting municipal or mixed municipal/industrial waste:

$$\frac{\text{kkg/day} \times 260\ (\text{day/yr})^{*}}{17{,}850\ \text{kkg/ha}} = \text{hectares filled annually} \qquad (3\text{-}2)$$

Occasionally, the exact amount of waste received by a given facility may be reported in state-supplied inventory data. A few states (e.g., Texas) provide data on the size of the population served by each municipal facility. Using per capita waste generation estimates for the subject population, one can convert "population served" into "kkg/day of waste generated," equivalent in this case to the amount of waste received by the facility. Per capita waste generation ranges from about 1 kg/day for rural populations to about 4.5 kg/day for urban populations. The nationwide average is 2.3 kg per capita per day (City of Ann Arbor 1981; NEMCOG 1980).

These numbers can be used in the following equation (note that municipal waste generation is computed on the basis of a complete 365-day year):

$$\frac{\begin{array}{c}\text{daily per capita}\\ \text{waste generation}\end{array} \times 365 \times \text{population served}}{17{,}850\ \text{kkg/ha}} \qquad (3\text{-}3)$$

$$= \text{hectares filled annually}$$

Capacity data may also be expressed in terms of acre-feet (one acre-foot is equivalent to 1,220 m^3). This can be converted into area by assuming that average trench depth is 10 m. EPA's Hazardous Waste Data Management System (HWDMS) provides capacity data in this form for each hazardous waste landfill (see Section 2.3.3(4), Exhibit D-1, and Table D-4 in Appendix D.). However, this figure represents the total proposed area of the facility, which is not necessarily equivalent to actual area. The reason is that permit applicants often claim for their facility a larger area than they intend to use immediately, in order to allow for future expansion. Assuming that the proposed area is indeed equivalent to operating area, the area filled per year can be calculated on the basis of a presumed ten-year lifespan for the average landfill (USEPA 1979b). These calculations have a low confidence level because of the many assumptions involved.

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*Represents the average number of landfill operating days per year.

An alternative method for estimating off-site hazardous landfill areas is to consult Table 20. The total off-site hazardous landfill area utilized annually in the subject EPA Region can be divided by the number of hazardous landfills in that Region (see Table 21) to obtain an estimate of the average area utilized in a single landfill. Despite the wide variation in individual landfill sizes, this method is probably more accurate than the preceding one, since Table 20 is based on actual amounts of hazardous waste landfilled in one year and thus fewer assumptions are involved.

3.1.5 Additional Considerations for Modeling Chemical Releases from Landfills

There are several parameters that may not be specifically considered as input data which must be taken into account when landfills are modeled. For large-scale exposure assessments where many landfills must be considered, the number of landfills containing the chemical(s) of interest must be known. In addition, the presence of a liner or leachate collection system, the extent of waste preprocessing, and several other factors should be known. Each of these factors is discussed below.

(1) Number of facilities. The total number of sanitary landfills and open dumps in operation in 1983 is given in Table 17 for each state. The exact number of municipal landfills currently in operation is not known. In 1976, the Waste Age Survey reported 15,821 sites; in 1977, 14,126 landfills were counted. There are two conflicting estimates for 1978, both based on estimated updates of the 1977 survey; these are 18,307 (USEPA 1979b) and 14,689 (USEPA 1980f). Sources of error and uncertainty include the inadequacy of state-supplied data and the increasing rate of landfill closings. Future trends are difficult to predict because of the changing regulatory climate.

Industrial on-site landfills (hazardous plus nonhazardous) are estimated by state in Table 22 and by Standard Industrial Classification (SIC) code in Table 23.

Table 20. Off-Site Hazardous Landfill Area Utilized Annually

EPA Region	Estimated total waste disposed of, thousand wet kkg	Total landfill area[a], hectares	Number of landfills	Area per landfill, ha
1	6	0.2	1	0.2
2	375	12.5	2	6.3
3	170	5.7	3	1.9
4	226	7.6	2	3.8
5	330	11.0	11	1.0
6	650	21.7	10	2.2
7	62	2.1	3	0.7
8	unknown	-	none[b]	-
9	822	27.5	10	2.8
10	59	2.0	2	1.0

[a] Derived on basis of assumptions explained in text (Section 3.1.4(4)(d)). Assumed that typical landfill capacity is 29,900 wet kkg per hectare.

[b] No permitted sites; the number of landfills improperly receiving hazardous waste is unknown.

Source: USEPA 1980b and Versar estimates.

Table 21. Commercial Off-Site Hazardous Waste Disposal Facilities
Offering Landfilling Services in 1980 by EPA Region.
(quantities in thousands of wet kkg)

EPA Region	Number of facilities	Amount of waste handled	Percentage of off-site hazardous waste handled[a]	Percentage of total hazardous waste handled[b]
1	1	6	1.1	0.5
2	2	375	37.9	12
3	3	170	19	3.9
4	2	226	17.2	2.2
5	11	330	13.5	5.1
6	10	650	50.6	6.2
7	3	62	14.5	5.2
8	0	0	0	0
9	10	822	94.7	29.0
10	2	59	12	5.9
TOTAL	44	2,699	28.7	6.5

[a] Percentage of off-site handled hazardous waste that is landfilled.
[b] Percentage of total hazardous waste generated in region that is landfilled in commercial off-site facilities.

Source: USEPA 1980b.

Table 22. Industrial On-Site Landfills by State[a]

State	Number of landfills
Alabama	1,150
Alaska	74
Arizona	469
Arkansas	652
California	8,648
Colorado	638
Connecticut	1,580
Delaware	125
Florida	2,218
Georgia	1,694
Hawaii	151
Idaho	275
Illinois	4,580
Indiana	1,890
Iowa	805
Kansas	691
Kentucky	723
Louisiana	845
Maine	432
Maryland	757
Massachusetts	2,497
Michigan	4,412
Minnesota	1,372
Mississippi	608
Missouri	1,514
Montana	201
Nebraska	382
Nevada	91
New Hampshire	313
New Jersey	3,625
New Mexico	211
New York	7,693
North Carolina	1,985
North Dakota	104
Ohio	4,488
Oklahoma	756
Oregon	1,093
Pennsylvania	4,368
Rhode Island	660
South Carolina	871
South Dakota	116
Tennessee	1,236
Texas	3,480
Utah	300
Vermont	190
Virginia	1,029
Washington	1,221
West Virginia	411
Wisconsin	1,998
Wyoming	84
TOTAL	75,705

[a] Including hazardous waste landfills.

Source: USEPA 1979b.

Table 23. Estimated Number of Industrial Landfills By Size Category

SIC code	Industry	Number of plants generating 0-45 kkg/day[a] (0-50 TPD) solid waste	Number of plants generating 45-180 kkg/day[a] (50-200 TPD) solid waste	% of all plants landfilling on-site	Number of on-site landfills		
					0-45	45-180	180+ kkg/day[a]
20	Food processing	28,120	63	22	6,186	14	0
21	Tobacco	272	-	22	60	0	0
22	Textile mill production	7,201	-	22	1,584	0	0
23	Apparel	24,438	-	22	5,376	0	0
24	Wood products	33,937	12	22	7,466	3	0
25	Furniture	9,233	-	22	2,031	0	0
26	Paper and allied products	6,038	-	22	1,328	0	0
27	Printing, publishing	42,069	34	0	0	0	0
28	Chemicals and allied products	11,317	108	40	4,527	43	0
29	Petroleum	2,016	-	20	403	0	0
30	Rubber and plastics	9,168	69	0	0	0	0
31	Leather	3,197	4	5	160	0	0
32	Stone, clay	15,993	22	22	3,518	5	0
33	Primary metals	6,728	64	20	1,346	13	0
34	Fabricated metals	29,450	75	22	6,479	16	0
35	Non-electrical machinery	40,792	-	70	28,554	0	0
36	Electrical machinery	12,270	-	0	0	0	0
37	Transportation equipment	8,661	141	22	1,905	31	0
38	Professional and scientific instruments	5,983	-	22	1,316	0	0
39	Miscellaneous manufacturing	15,187	-	22	3,341	0	0
	TOTAL:				75,580	125	0

[a] kkg denotes metric tons.

Source: USEPA 1980f.

Almost all industrial on-site landfills fall within the 0-50 tpd (0-45 kkg/day) size category (Table 23). These are filled at the approximate rate of one-half hectare per year (based on Equation 3-1). The total on-site landfill area filled each year by each SIC group is shown in Table 24; these estimates were obtained by applying the conversion factor from Table 18 to industrial waste generation data from USEPA 1979b. The approximate area of municipal landfills used annually is estimated in Table 25 based upon the same assumptions applied to other published data (USEPA 1977).

(2) Liners. A few models currently take into account the effect of natural or synthetic liners on pollutant migration. Others do not; this may represent an important gap in the ability to predict emissions from landfills, depending on the particular model chosen.

Ideally, the bottoms of all landfills should be lined with an impermeable membranous lining; the proposed regulations of many states and current federal regulations make this mandatory for new sites. Existing landfills may or may not be lined. In actual practice, the 1983 Waste Age Survey (Peterson 1983) reported that only 37 out of nearly 13,000 municipal landfills in the U.S. currently operate with liners. In the absence of specific information for each site, age is perhaps the best indicator as to whether a liner is present. When considering regional data, it is reasonable to assume that older nonhazardous and municipal sites (ca. 10 years) are not lined. In the case of a specific site that is known to be lined, an assumption will have to be made as to the rate of leakage or tearing. The information resources investigated in this study provided no tools with which to estimate the leakage rate. The effects of leachate on liner permeability are currently under study (Haxo 1976, 1979, 1980; USEPA 1983b). Since hazardous waste disposal sites must meet more stringent operating and design criteria, many of them are lined. Consult the regulations of the subject state; these may prescribe layers of earth compacted to given specifications in lieu of synthetic or natural clay liners.

(3) Leachate collection. RCRA hazardous waste regulations require all new sites and existing sites that will be expanded to have some kind of leachate collection system. This would affect release estimates, reducing groundwater contamination to zero (at least theoretically) and adding steps to the methodology, since collected leachate must itself be disposed of in some way. Leachate disposal options include various treatment methods, landspreading, and recirculation to active portions of the fill. At the present time, however, only 26 out of approximately 12,000 municipal facilities are known to collect leachate (Anon. 1981c). It is extremely unlikely that leachate is being collected at on-site nonhazardous industrial landfills.

Table 24. Industrial On-Site Landfill[a] Acreage Used Annually

SIC Code	Industry	Total kkg/yr disposed ($x10^6$)	Total TPY[b] disposed ($x10^6$)	Hectares	Acres
22	Textile-mill products	3.7	4.1	126	315
23	Apparel	12.7	14.0	431	1,077
24	Wood products	17.7	19.5	600	1,500
25	Furniture	4.8	5.3	163	408
26	Paper and allied products	3.2	3.5	108	269
28	Chemicals and allied products	11.8	12.9	397	992
29	Petroleum	0.91	1.0	31	77
30	Rubber, plastics	0	0	0	0
31	Leather	0.36	0.4	12	31
32	Stone, clay	8.5	9.3	286	715
33	Primary metals	3.5	3.8	117	292
34	Fabricated metals	15.7	17.3	532	1,331
35	Nonelectrical machinery	67.5	74.2	2,283	5,708
36	Electrical machinery	0	0	0	0
37	Transportation equipment	5.3	5.8	178	446
38	Professional and scientific instruments	3.1	3.4	105	262
39	Miscellaneous manufacturing	7.9	8.7	268	669

[a] Includes hazardous waste landfills.
[b] TPY = tons per year.

Source: Conversion factor from Table 18 applied to industrial waste generation data from USEPA 1979b.

Table 25. Municipal Landfill Acreage Used Annually

EPA Region	Number of landfills	Acres	Hectare
I	1,122	190	76
II	936	1,340	536
III	930	1,130	452
IV	1,611	1,930	772
V	2,973	3,550	1,420
VI	2,706	3,240	1,296
VII	1,277	1,530	612
VIII	1,206	1,440	576
IX	890	1,070	428
X	1,038	1,250	500

[a] Based on estimated total of 14,689 landfills (USEPA 1980f).

Source: Conversion factor for municipal landfill capacity (Table 18) applied to 140 million tons municipal waste generated annually in the U.S. (USEPA 1977) distributed regionally on the basis of landfill size distribution by state (Anon. 1981c, Waste Age Survey).

(4) Preprocessing. The preprocessing of waste by shredding and/or baling affects the production and composition of leachate and gas from the waste, and would also affect the leaching rates of chemicals from the waste. The nature and extent of these effects are still under investigation (Hentrich et al. 1979; Eifert and Swartzbaugh 1977). Currently, only 33 facilities reportedly mill, shred, or grind waste (Anon. 1981c). These procedures are not applicable to most industrial waste.

3.1.6 Estimating Emissions from Broad Geographical Regions

The exact method of estimating environmental releases from broad geographical regions will depend on the nature of the exposure assessment and the models used; however, a general approach is outlined below. Data on the soil, climatic, and other conditions available in the region of interest can be combined or averaged with the generic data compiled in this report. From these data, one or more hypothetical landfills embodying these parameters can be designed. An exposure assessment then can be conducted using the hypothetical landfill(s) as the source. Alternatively, sets of high and low values can be selected to represent the range of these variables, for which modeling of releases can then be performed. In designing hypothetical landfills, site-specific operational characteristics (e.g., capacity, depth of fill, density of waste accepted) can be assumed to average out to the figures given in Section 3.1.4(4).

3.1.7 Monitoring

Estimates of chemical releases and concentrations can be checked against any available monitoring data. However, monitoring data are uncommon and are limited to few, if any, toxic chemicals. About 12 percent of all functioning landfills are known to have monitoring wells (Petersen 1983). Monitoring data at landfills may include one or more of the following types: leachate, groundwater, soil particles, or waste composition. Monitoring data are also submitted to the applicable state agency and to EPA regional offices in quarterly reports. These are not available except by personal visit to the agency and a manual search of their files. Additional data have been derived from physical models representing scaled-down replicas of landfills (Eifert and Swartzbaugh 1977, Hentrich et al. 1979, Streng 1977, Wigh and Brunner 1979). Extrapolation of monitoring data from one site to another is not advisable because of the many variables which affect releases of chemicals from a site, particularly site-specific physical, climatological, and operating conditions (Weston 1978).

3.2 Allocating Waste Streams to Landfill Sites - Stage IV Decision Tree

Using available information on the disposal practices used for various types of wastes and the design and operating characteristics of the different types of landfills, one can estimate the proportion of each individual waste stream that is likely to be disposed of at landfills in the study area. Because site-specific information is not readily available for most landfills, considerable individual judgment is needed.

For site-specific estimates, the output of Stage IV will be the location of each landfill receiving the subject waste, and the quantity of subject waste received by each landfill. For calculations of environmental releases that apply to broad geographic areas where the locations of individual sites are irrelevant, only the estimates of total landfill population and of the amount of waste received by one or more representative model landfills are necessary. Consult Section 3.1 for suggestions on parameter values to use in nationwide or regional exposure assessments.

For Stage IV determinations, consult the following sections:

For municipal landfills .... Section 3.2.1
For nonhazardous industrial landfills .... Section 3.2.2
For hazardous waste landfills .... Section 3.2.3

3.2.1 Municipal Landfills

Step 1. **Identify landfills that are probable candidates for disposal of the waste stream of interest and locate them on a map of the study area.**

Some states have compiled inventories of municipal landfills which list their locations (see Table B-1, Appendix B). For states not listed in Appendix B, contact the state solid waste agency, Table D-3, Appendix D, for this information.

Step 2. **Estimate the amount of the waste stream of interest disposed of at each facility (in quantity/year). Consider the capacity and operating characteristics of each facility (if available) as well as the distance from the source of waste.**

The distribution of this waste stream among the candidate sites will depend on the nature of the waste. For example, if it is a residential waste that is generated uniformly by the population, assume that its distribution among landfills is proportional to their relative capacities. If capacity information is not available, assume that the average rural landfill has a capacity of 0 to 45 kkg/day. Urban landfills are larger, and the Waste Age surveys (Table E-2, Appendix E) should be consulted to determine the most prevalent capacity range in the states included in the study area. Alternatively, if population data are available for the area served by each landfill, Equation 3-3 can be used to estimate landfill capacity (see Section 3.1.4(4)(d)).

Step 3. If no information is available for Step 2, assume that all of the waste stream of interest is disposed of within a few miles of its point of origin. The cost of hauling generally makes long-distance transportation of waste economically unfeasible. Allocate an amount of waste to each landfill on this basis, and produce a list of landfills in the study area that indicates the estimated amount of waste handled at each site. Then, use average climatological and geological data for estimating releases in Stage V.

3.2.2 Industrial Nonhazardous Landfills

Step 1. Determine the percentage of the waste stream of interest that will be disposed of on-site versus off-site. This information will be a useful tool in Step 2.

References already consulted for Stage III may have provided this information. If no information is available, proceed with Steps 2 and 3 below; then deduce the probable proportion of on- and off-site facilities based on the estimated numbers and capacities of each (see Stage III). Assume that all waste generated by facilities known to have on-site landfills is disposed of on-site.

Step 2. Identify the landfills that are probable candidates for disposal of waste stream of interest.

To locate off-site facilities,

- Determine whether the subject state supplies facility inventories. (Table D-3 lists phone numbers of applicable state agencies.) Consult these for locations; note whether any distinction is drawn between municipal and off-site industrial landfills. Otherwise use the nationwide Waste Age Surveys (see Tables 17 and 22) to get at least a rough idea of the number of potential industrial landfills in the state(s) of interest.

- Note that nonhazardous waste is often disposed of with hazardous waste to avoid the expense of separating waste streams. If this is likely to be the case with the waste stream of interest, conduct a HWDMS retrieval (Section 2.3.3(4) and Exhibit D-1 in Appendix D.)).

Step 3. Estimate the amount of the waste stream of interest disposed of at each facility. The output of this step should be a list of facilities and the estimated annual amounts of the waste received by each facility.

Consider the capacity and operating characteristics of each site (if available) as well as the distance from the source of waste. The cost of hauling generally makes long-distance transportation of waste economically unfeasible. Therefore, the waste is probably disposed of at the nearest facility of sufficient capacity to accept it. If the exact location of the facility cannot be determined, assume that the waste is disposed of within a few miles of its source of origin. Then, use average climatological and geological data for the county for calculations of Stage V releases.

3.2.3 Hazardous Waste Landfills

Step 1. Determine the percentage of the waste stream of interest that will be disposed of on-site versus off-site.

References already consulted for Stage III (Section 2.3.3(4)) may have provided this information. If no information is available, proceed with Steps 2 and 3 below; then estimate the probable proportion of on- and off-site facilities based on the estimated numbers and capacities of each (see Stage III). Assume that facilities with on-site capacity will treat and dispose of the waste on-site, provided that their facilities can handle the waste.

Step 2. Identify the landfills that are probable candidates for the disposal of the waste stream of interest.

a. Conduct a HWDMS retrieval to obtain facility locations (see Section 2.3.3(4) and Exhibit D-1 in Appendix D). (This may already have been done in Stage 3.) Be sure to include off-site commercial facilities in the retrieval.

b. Contact the subject state (see Table D-3) to verify and add to the list compiled in 2.a. Many states supply inventories of hazardous waste disposal sites, often specifying the exact types of wastes treated. (Although HWDMS may also supply this information, the data are considered unreliable.) One useful source of information is the State of Kansas, which supplies a list of all commercial hazardous waste handlers in the Midwest (see Exhibit B-2 in Appendix B).

Step 3. **Estimate the amount of the waste stream of interest disposed of at each facility (in quantity/year). The output of this step will be a list of facilities and the estimated annual amounts of the waste stream of interest received by each.**

Consider the capacity and operating characteristics of each candidate facility (if known) as well as the distance from the source of the waste. For facilities that are known to have on-site landfills, assume that all of the waste is disposed of there unless other on-site disposal methods are known to exist. Otherwise, the waste will probably go to the nearest commercial facility of sufficient capacity to accept it. Note that the capacity reported by HWDMS is the proposed capacity, which may not be the same as current operating capacity. See Sections 3.1.4 and 3.1.5 for suggestions on using capacity data. Note that information on types of waste accepted, if available (obtained in Step 2), may eliminate some sites from consideration. The amount of uncertainty in these estimates will vary depending on the assumptions used, but will generally be lower than for nonhazardous landfills.

3.3 Estimating Environmental Releases from Landfills - Stage V Decision Tree

Environmental releases will normally be estimated using a mathematical model. In Stage V, the user evaluates available information on design/operating features of the landfills in the study area. This information, in conjunction with the Stage IV estimates of the amount of waste received by each facility, is used as input to the model to estimate releases of chemical substances to air and groundwater. Ideally, the output of Stage V will be the total annual quantity of the subject wastes emitted to air, groundwater, and surface water from each individual landfill, or from statistically representative landfills in the case of broad regional estimates. For the steps required by Stage V for municipal landfills, see Section 3.3.1; for industrial (hazardous and nonhazardous) landfills, see 3.3.2.

3.3.1 Municipal Landfills

Step 1. Select a model to estimate environmental releases of the waste of interest.

For nationwide or broad regional estimates, see Section 3.1.6. Estimated total municipal landfill area used annually is summarized by EPA Region in Table 25. For site-specific determination, see Step 2.

Step 2. Assemble the data necessary to run the model.

The following types of data will probably be required for most relevant models.

- Climatological data
- Soil data
- Chemical data
- Geometric, application-specific data.

Climatological and soil data will be assembled from the data sources detailed in Section 3.1.4. Chemical information is available from standard reference manuals. Geometric, application-specific operational information may be more difficult to obtain.

Step 3. Estimate other operational parameters as needed for model input.

a. Pollutant loading. Determine the proper format for the pollutant quantities at the site that have been estimated in Stage IV (Section 3.2) and compile these data. The manner in which these data are input to the model will depend on a number of factors, especially on whether the waste mass is consolidated or well-distributed. Consult Section 3.1.4(4)(c) for an explanation of the factors involved.

b. Depth to groundwater can be determined from statewide computerized data bases, if they are available for the subject states, or from one of the USGS data bases described in Section 3.1.4(a). In the absence of such data, a default value (or set of limiting values) can be selected on the basis of the Surface Impoundment Assessment (SIA) data base (see Section 5), soil maps, wetland distribution data for the subject state (see Section 3.1.4), or other general references.

c. Depth of various soil zones. Section 3.1.4(4)(b) provides default figures for depth of fill, earth cover, and similar data. Unless there is information to the contrary, assume that no liner or leachate collection system is present.

d. Landfill size (surface area). Individual landfill capacity is occasionally included in state-supplied inventory data. In the absence of site-specific data, assume that a rural landfill has a capacity of 0-45 kkg/day. Urban landfills are larger; consult the Waste Age Surveys (Tables E-2, Appendix E) to ascertain the most common capacity range for larger landfills within the subject state. To convert capacity into landfill volume, use Equation 3-2 (Section 3.1.4(4)(d)). Landfill area is then calculated by dividing the volume by the landfill depth (if known; otherwise use an average depth of 10m.). This method should be reasonably accurate when the exact landfill capacity is known. The amount of error involved in these estimates depends on whether site-specific or generic data are used.

Facility inventories of some states provide data on populations served by each site. In this case, landfill area can be estimated by Equation 3-3 (Section 3.1.4(4)(d)).

Step 4. Using the model of choice and the assembled input data, estimate environmental releases to air and groundwater for each landfill receiving the waste stream of interest.

Output should include the following:

- Flux of the subject chemical entering the groundwater after a given period of time.
- Flux of the subject chemical volatilizing from the soil into the atmosphere after a given period of time.
- Concentration of subject chemical remaining in each designated soil zone after a given period of time.

Step 5. If monitoring data are available (which is highly unlikely), compare them with the predicted concentrations of the chemical of interest.

Comparison of monitoring data with release estimates requires considerable expertise, because there are many variables that complicate the comparison, including problems related to lab analysis and temporal and spatial variation in pollutant concentration. If estimated concentrations do not correlate with measured values, use best judgment to evaluate the discrepancy. Estimated releases may be used as input in the analysis of environmental fate and pathways and in the final exposure assessment, discussed in Volume 2 (for ambient exposure) and Volume 5 (for drinking water exposures).

3.3.2 Industrial Landfills (Hazardous and Nonhazardous)

Estimation procedures for environmental releases are similar to those for municipal landfills, with some additions.

Step 1. See Step 1 of Section 3.3.1. The total on-site industrial landfill area used annually is summarized by SIC code in Table 24. Off-site landfill disposal of industrial nonhazardous wastes may be presumed to occur at municipal sites, except in states that supply separate data for industrial and municipal sites.

Step 2. See Step 2 of Section 3.3.1.

Step 3. a. See Step 3.a of Section 3.3.1. Also, note the following: In the case of manufacturing wastes, it is important to know whether the wastes are generated during a batch or continuous process. (This information may have been compiled for the ambient exposure scenario.) This will determine whether the subject pollutant will be concentrated in a few individual cells or spread more or less evenly through the landfill.

b. See Step 3.b of Section 3.3.1.

c. See Step 3.c of Section 3.3.1. Also, note that the presence of liners and leachate collection systems will have to be taken into account.

d. See step 3.d of Section 3.3.1. Also, for hazardous waste sites, the HWDMS provides data on the proposed facility capacity. Care should be taken in using these data, however, as this does not necessarily represent actual operating capacity. Note that Equations 3-1 and 3-3 assume that the subject waste is being generated continuously. In cases where the waste results from a batch manufacturing process, the necessary adjustments should be made to reflect the smaller volume occupied by the waste. (A similar adjustment will be necessary when pollutant loading is estimated; see Step 3.a above). When the subject pollutant is disposed of only a few days a year, note that the average depth of a single cell, representing one day's accumulation of waste received, is about 3 meters.

Step 4. See Step 4 of Section 3.3.1.

Step 5. See Step 5 of Section 3.3.1.

4. LAND TREATMENT

This section presents methods for evaluating exposure to chemical substances from land treatment. There is sometimes little site-specific information on land treatment, with the exception of hazardous waste land treatment sites and some municipal waste sites. Therefore, the kinds of data available will be more suited to nationwide large-scale exposure assessments than to more detailed assessments, unless site-specific information is collected. Some generic data to support such assessments were developed in this methods development effort. The background material on which the methods are based is given in Section 4.1, followed by the Stage IV and Stage V decision trees in Sections 4.2 and 4.3, respectively.

4.1 Background Information

Soil is a natural environment for the deactivation and degradation of many waste materials through physical, chemical, and microbiological processes. Land treatment is a disposal technique by which liquid wastes or sludges are mixed with the surface soil to promote these processes, particularly microbial decomposition of the organic fraction. If the land treatment site is managed properly, the treatment processes described below can be carried out repeatedly on the surface of a disposal site. In practice, sludges or wastewaters are either hauled or piped directly from the treatment plant or from an interim storage or evaporation lagoon to the disposal site. The sludges are applied to the land by spraying, spreading, or subsurface injection. The field may then be disked or plowed by conventional farm cultivation equipment. Nutrients or other soil amendments may be added to increase biological activity, and the soil/waste mass may be mixed periodically to maintain aerobic conditions.

The process of land treatment appears to work in a wide range of climatic conditions; however, warm, humid climates offer the most favorable conditions since biodegradation of the organic fraction is enhanced with adequate moisture and high temperatures. Land cultivation has been used in cold and dry climates, but the waste degradation rates under such conditions are relatively slow. Many sites are located in relatively wet areas, occasionally within a few meters of the water table (so that pooling may occur). These are examples of poor site selection; besides increasing contamination potential, excessively wet conditions hinder proper mixing of soil and waste.

Landspreading promotes the aerobic decomposition of organic waste. This reduces its volume, prevents the formation of unwanted gases, and minimizes the intensity of leachate problems. The site may be returned to almost any other land use, often including agriculture. Active land treatment sites are often used for growing crops. Possible disadvantages of this method include the need for relatively large tracts of land, long-term release of waste to the atmosphere and groundwater, impact on vegetation grown on the site, and uptake of chemical substances by food-chain crops (Ross and Phung 1978).

The EPA Office of Solid Waste (OSW) has recently published a technical resource document on hazardous waste land treatment which is the most comprehensive and up-to-date source available on land treatment in general (USEPA 1983a). That document includes a survey of hazardous waste land treatment sites as well as general information on recommended practices. Other sources include a state-of-the-art study sponsored by the EPA's Municipal Environmental Research Laboratory (Phung et al. 1978), and various research reports (Berkowitz et al. 1980, Phung et al. 1977, and Ross and Phung 1978). Nationwide, 221 facilities have applied for Resource Conservation and Recovery Act (RCRA) permits for the land treatment of hazardous waste (Table D-7 in Appendix D), and a recent survey located 197 operating facilities (USEPA 1983a).

4.1.1 Types of Waste Treated

Several types of wastes are treated by landspreading. This includes wastewaters and sludges from Publicly Owned Treatment Works (POTWs), wastewaters and sludges from private industries (including some hazardous wastes), and municipal solid waste. Current land treatment practices for each of these wastes are discussed below; estimates of the volumes of waste landspread by a few industries are provided in Table 26.

(1) POTW wastewaters. POTW effluents are sometimes landspread (usually after secondary treatment). About 600 communities in the U.S. use this practice, which is most prevalent in arid or semi-arid areas (Culp 1979).

There are three basic approaches to land treatment of liquid POTW effluent: irrigation, overland flow, and infiltration-percolation. In the irrigation method, wastewater is applied to land by fixed or moving sprinklers or by surface spreading. In the overland flow system, wastewater is sprayed over the upper edges of sloping terraces and flows down the hill through grass and vegetation; the runoff wastewater is diverted into collection channels. The infiltration-percolation method is primarily a groundwater recharge system whereby wastewater (after secondary treatment) is put into spreading basins so that it can percolate into the ground. This method does not attempt to recycle nutrients through crops.

Table 26. Landspreading Activity, Dry Weight

Activity	Current volume kkg/yr
Textiles	5
Petroleum	50
Pulp and Paper	Negligible
Leather	24
Food Processing	
- dairy products	120
- breweries	3
- wineries	217
- canned and frozen foods	400
- feedlots	62,000
Municipal wastewater treatment	
- to food chain land	750
- nonfood chain land	250
- giveaway/sale	500
Total except feedlots	2,319
TOTAL	64,319

Note: The estimates in this table were taken directly from the source, thus do not reflect more recent data provided in Table 6 (Section 2.3.3 (2) and in the recent OSW survey of hazardous waste land treatment sites (USEPA 1983a).

Source: USEPA 1979b.

(2) POTW sludge. Nationwide about 24 percent of the POTW sludge generated is applied to land, one half of which is landspread on food chain land (see Table 6 in Section 2.3.3(2)).

Several cities apply liquid sludge to cropland. Larger cities may pump the sludge through pipelines to the disposal site. The city of Chicago ships POTW sludge by barge to strip-mined land 200 miles away to restore the land to agricultural uses. In most cases, however, sludge is transported by tank truck. Economic considerations usually prohibit the hauling of sludge more than a few miles from the point of origin (Phung et al. 1978).

Sludge may be dewatered and dried and applied to land as a soil conditioner. The city of Denver plows dry sludge cake into the ground at a nearby disposal site. Nationwide, approximately 18 percent of the POTW sludge is distributed for marketing (Table 6 in Section 2.3.3(2)). For example, Houston sells its dried sludge to a contractor in Florida to fertilize a citrus grove. Milwaukee markets bagged heat-dried POTW sludge through large distributors in all 50 States and some foreign countries. It is presently impossible to track the ultimate individual disposal sites of wastes distributed in this manner.

(3) Industrial wastewaters. Some land treatment of wastewaters has been practiced by the food processing, pulp and paper, textile, tannery, wood preserving, and pharmaceutical industries. At most locations, the practice is primarily used for wastewater treatment, rather than for land reclamation, so that little or no effort has been made to incorporate wastewater into the soil (Ross and Phung 1978). Table E-5 in Appendix E provides a nationwide breakdown of the number of hazardous waste land treatment sites by industry, based on a survey reported in USEPA 1983a. That survey did not differentiate between sites receiving industrial wastewaters and sites receiving industrial sludges.

(4) Industrial sludges. Land-treated industrial sludges are either organic (e.g., oil refinery, paper and pulp, and fermentation residues) or treated inorganic wastes (e.g., steel mill sludge) containing low concentra- tions of extractable heavy metals. When the sludge is applied to agricultural land, it is primarily for disposal. The sludge is also used as soil amendment.

Among industrial sludges, oil refinery wastes are disposed of most extensively by this method. (Of the 197 hazardous waste land treatment sites identified in the OSW-sponsored survey (USEPA 1983a), 101 received petroleum refinery wastes. Types of oily waste disposed of include cleanings from crude oil, slop emulsion, separator bottoms, and drilling muds. The sludge is applied to the land by spreading it to a depth of about 7 to 20 cm and disking it into the soil. Mixing intervals vary from once per week over several weeks to twice per year. The practice is strictly for disposal; no crops or vegetation other than weeds grow at the sites (Ross and Phung 1978). Disposal is usually on-site. See Table E-5 in Appendix E for a listing by industry of the number of hazardous waste sites. As stated above, this table does not distinguish between industrial sludges and industrial wastewaters.

An increasing number of off-site commercial operators are treating wastes, especially hydrocarbons, by landspreading. Some hazardous waste is landspread at commercial facilities, often after treatment in solar evaporation ponds. Table 27 shows (by EPA Regions) quantities of waste treated in off-site commercial facilities.

It has been estimated that only about 3 percent of all industrial sludge and wastewater is suitable for disposal by land treatment (Ross and Phung 1978).

(5) Landspreading of municipal solid refuse. Although this practice is uncommon at the present time, a program for landspreading shredded municipal refuse has been instituted by the City of Odessa, Texas. About one fourth of Odessa's refuse is currently being disposed of in this manner; the goal of the project is to landspread 90 percent of the city's refuse. The primary purpose of the undertaking is for land reclamation. So far, 130 ha (50 acres) of the 610-ha (1,500 acres) site is being so utilized. Application rates are approximately 220 kkg tons per hectare (100 tons/acre). Whether other cities have similar programs is unknown. No significant increase in nationwide landspreading of municipal refuse is expected (Phung et al. 1977, 1978).

4.1.2 Environmental Impacts and Environmental Releases

There is a growing body of information on the extent of environmental contamination from land treatment of waste. It is somewhat limited partly because impacts are chronic rather than acute; pollutants may move slowly and take decades to leach through soil into groundwater. The previously mentioned OSW technical resource document (USEPA 1983a) is the most comprehensive source available on the processes associated with environmental releases from land treatment sites.

Wastes applied to surface soils are susceptible to surface runoff from precipitation, although some sites contain drainage control facilities. Flood problems are occasionally reported and are due to poor site selection (Phung et al. 1978).

Groundwater quality may be impaired if leachate penetrates to aquifers. Waste pretreatment can reduce the potential for this problem. The waste load applied to the soil can be regulated by pretreatment, process modification, or the addition of soil amendments (USEPA 1983a). Most organic compounds are eventually decomposed by soil microorganisms.

Table 27. Commercial Off-Site Hazardous Waste Disposal Facilities Offering Land Treatment/Solar Evaporation Services in 1980[a] by EPA Region

EPA Region	Number of facilites	Amount of waste handled, thousands of wet metric tons	Percentage of off-site wastes handled [c]	Percentage of total wastes handled[d]
I	0	0	0	0
II	0	0	0	0
III	1	NA	NA	NA
IV	1	_[b]	_[b]	_[b]
V	1[e]	NA	NA	NA
VI	3	117[b]	11.4[b]	1.1[b]
VII	0	0	0	0
VIII	0	0	0	0
IX	6	345	64.5	12.2
X	1	75	21.6	7.5
TOTAL	13	537	8.8	1.3

NA - Data not available

[a] Includes both land treatment and solar evaporation because the two practices are often closely related. Evaporation ponds are often used for physical separation and dewatering, which is followed by application of the sludges to the land.

[b] Data for Regions IV and VI were combined to protect confidential information.

[c] Percentage of all off-site handled waste that is land-treated.

[d] Percentage of all hazardous waste generated in the Region that is land-treated off-site.

[e] Currently inactive (7/81)

Source: USEPA 1980b, USEPA 1983a.

Unless the soil is overloaded with toxic substances, land treatment is not likely to pose a serious threat to groundwater quality (Ross and Phung 1978). Early detection of leakage through a properly designed and maintained monitoring system remains the best way to prevent serious contamination (USEPA 1983a).

Environmental releases to the air may result from landspreading activities. Wastewaters and sludges may volatilize on exposure to the atmosphere, impairing air quality in the disposal area. Volatilization may result in a release to the air, although much of the readily volatile fraction would have come off during waste handling prior to delivery to a disposal site. Subsurface injection of the waste or mixing it with soil can alleviate these problems, but it may not eliminate them (Ross and Phung 1978).

Probably the most significant potential human health hazard is the uptake of chemical waste by food-chain vegetation. Long-term effects of land treatment on crop quality and the food chain are not known. Toxic metal accumulation in particular may pose a serious threat.

If a soil is burdened with more waste than it can absorb, it may become anaerobic, resulting in nuisance odors and failure of the system to degrade the organic matter effectively. Furthermore, unless the wastes are decomposed to nonharmful products, the soil zone receiving the wastes could eventually become overloaded. As a result, disposal activities at the site would have to be terminated, rendering the site unusable for alternative purposes for many years (Ross and Phung 1978; USEPA 1983a).

4.1.3 Location of Sites

In a detailed exposure assessment, individual sites should be located before releases are estimated. This is not always possible, however, because of the lack of reliable information on land treatment sites that receive other than hazardous wastes.

On-site industrial facilities by definition are located at the manufacturing plant. Hazardous waste land treatment facilities, both on-site and off-site can be identified by a retrieval from the Hazardous Waste Data Management System (HWDMS) (see Section 2.3.3(4) and Exhibit D-1 in Appendix D).

The OSW survey of hazardous waste land treatment sites reported in USEPA 1983a, however, contains more information on individual sites than does the HWDMS data base.

For each site in the U.S. the following data were collected:

- Name and address of facility
- EPA ID number
- Phone number and contact
- Size (acres)
- Type (by RCRA hazardous waste code) and amount of waste (tons/yr)
- Industry description and SIC code
- Additional available miscellaneous information

The user must consult USEPA 1983a for this site-specific information, which was too voluminous to include in this report. Summary data from the survey, however, are included in Appendix E of this report. Figure E-1 and Table E-4 summarize the geographic distribution of hazardous waste land treatment sites in the U.S. Table E-5 lists the location of all known sites by industry (including SIC code).

Fields used for off-site landspreading of nonhazardous industrial and POTW wastes may be disposal facilities as such, operated by municipalities or commercial commercial disposal firms, or they may be privately-owned farmland whose primary purpose is crop production. In neither case are they likely to be listed in state-supplied facility inventories. If the sites are not listed, it may be reasonable to assume that they are located close to the source of the waste, since long-distance transportation of wastewaters and sludge is not economically feasible. Environmental release estimates can then be based on general climatological and soil data for the entire county.

There is currently no way to determine the ultimate disposal site of sludge that is dewatered and distributed for marketing.

4.1.4 Estimating Environmental Releases

The general discussion in Section 3.1.3 on modeling releases from land disposal sites is applicable to land treatment sites. Models used to estimate releases from land treatment sites should take into account the reduction in chemical concentrations over time due to biodegradation and chemical and photochemical degradation. Environmental releases from land treatment sites can be predicted by several models, including the Pesticide Root Zone Model (PRZM) and SESOIL. A description of SESOIL is included here to illustrate in general the issues and procedures associated with modeling environmental releases from land treatment sites. An example of a practical application of SESOIL is included in the companion volume on assessing exposures from drinking water (Volume 5).

SESOIL was developed by M. Bonazountas of A.D. Little, Inc., (ADL) of Cambridge Massachusetts and is a mathematical model for long-term environmental pollutant fate simulations that describes water transport, pollutant transport/transformation, and soil quality. It may be used to predict leachate contamination of groundwater as well as gas emissions to the atmosphere (Bonazountas and Wagner 1981). SESOIL has been applied to several waste disposal practices, including industrial landspreading (Bonazountas et al. 1981) and the disposal of buried solvent drums (Wagner and Bonazountas 1981).

SESOIL is designed to be used to estimate environmental releases on a site-specific basis as well as across broad regions or nationwide (using hypothetical or "average" environments). Model simulations are based on a three-cycle rationale, the water cycle, sediment cycle, and the pollutant cycle. The water cycle takes into account rainfall, infiltration, exfiltration, surface runoff, evapotranspiration, groundwater runoff, snow melt, and interception. The sediment cycle includes sediment resuspension due to wind and sediment washload due to rain storms. The pollutant cycle characterizes convection, diffusion, volatilization, adsorption/desorption, chemical degradation, complexation of metals, biological actions, hydrolysis, oxidation, and nutrient cycles. The user has the option of running the model on one of four different levels of spatial and time variations.

Typical outputs of SESOIL include:

- Temporal and spatial pollutant concentration distributions in soil-air, soil-moisture, and on soil particles of the soil compartment.

- Leachate migration in the unsaturated zone.

- Pollutant migration (releases) from the unsaturated soil zone to the air.

Aside from predicting chemical distributions in the unsaturated zone, other SESOIL outputs include hydrologic relationships among precipitation, surface runoff, infiltration, evapotranspiration, soil moisture and groundwater runoff. Concentrations are reported according to the level of application.

An advantage in using SESOIL for modeling of the unsaturated zone is that it can be used with input and output data files that have been developed to support its use. (Table 16 in Section 3 provides a subset of the SESOIL soil data file.) SESOIL can provide a detailed mechanism, with a high degree of accuracy, to model contaminants in the unsaturated zone with minimal effort. The results can also be used as input into a model designed for the saturated zone.

4.1.5 Model Input Data

Table E-3 in Appendix E lists all the input data that may be required to run the SESOIL model. (Not all the parameters are required for most applications.) There are five classes of input data: climatological, soil, chemical, application-related geometric, and application-specific.

Soil, climatological, and chemical data can be obtained as described previously for landfills. The range of possible parameter values may be slightly narrower than for landfills, however, because the soil and climate must be conducive to biodegradation. Some information related to these parameters is provided below, followed by a discussion of information related to selected geometric, application-specific characteristics.

Land treatment sites are usually relatively flat, with slopes less than 1 to 5 percent. The soils at these sites vary over a wide range of texture and permeability. One site, for example, started operating in beach sands, although eventually the drilling muds being disposed of there significantly changed the texture of the surface soil (Phung et al. 1977). In general, land treatment sites should not be established on extremely deep, sandy soils because waste migration to groundwater may result. The best soils for land treatment include; loam, silt loam, clay loam, sandy clay loam, silt clay, or sandy clay (USEPA 1983a).

The nature and extent of on-site vegetation will affect the evapotranspiration rate and hence the environmental release rate. Land preparation generally entails scarification of the surface to expose as much soil area as practical. Vegetation is usually removed, but the smaller bush and grass may be left in place to be mixed with the waste. Grasses in the disposal plot will become established if the plot is left idle for some time.

Many sites are farmed extensively, being used for wheat, corn, or other crops. Active land treatment sites are frequently used for turf farming (Berkowitz et al. 1980).

The range of possible climatological parameter values may be slightly narrower than for landfills, because warm, humid, climates offer the most favorable conditions for biodegradation. Figure E-1 in Appendix E shows that the land treatment sites are generally located in the south, southeast, and west.

Among the required application-related geometric and application-specific parameters for modeling are several parameters that were investigated or suggested for use in the methodology. These parameters include the following:

- Depth to groundwater
- Depth of various soil zones
- Surface area of the site
- Pollutant loading

Estimation of the depth to groundwater and the depth of the soil zones was discussed in the section on landfills (Section 3.1.4 (4)). The discussion applies equally well to land treatment sites, with the following modification: the layer of waste incorporation at land treatment sites usually will be considered the upper unsaturated soil layer for the purposes of modeling. The depth of this layer may range anywhere from a few centimeters to 60 centimeters.

The surface area of land treatment sites is not always available and must sometimes be estimated. The surface area of hazardous waste land treatment sites (in acres) was tabulated in the recent OSW survey (USEPA 1983a). Surface area is also available in the HWDMS as "proposed capacity" (in hectares). Proposed capacity, however, is not necessarily equivalent to the area actually used for waste treatment; area data from the HWDMS may be used as an upper limit. For industrial facilities for which no information on surface area is available, a "typical" surface area might be estimated from the data in the OSW survey. Figure E-2 in Appendix E gives the size distribution of land treatment facilities in that survey. Although the facility sizes range from 0.005 (.002 ha) to 1668 acres (675 ha), the median size is only 13.5 acres (5.5 ha), and the distribution is skewed towards the small facilities. If necessary, the user can obtain a similar estimate for the industry or region of interest by examining the survey data for the sites of interest (in USEPA 1983a). It seems reasonable to assume that land treatment sites treating nonhazardous industrial waste will have similar surface area distributions as those sites treating hazardous wastes.

Surface area for municipal wastewater treatment plants can be estimated based on the fact that they need an estimated 40 to 240 ha (100 to 600 acres) per mgd (million gallons per day) capacity (Culp 1979). The plant capacity is available from the Needs Survey data base as discussed in Section 6 and Exhibit H-1 and Table H-8 in Appendix H.

In the absence of more reliable information, the surface area of a land treatment site can be calculated as shown in Equation 4-1 in cases where the application rate, the quantity of waste applied per unit area, and the frequency of application are known or can be estimated.

$$S = \frac{A}{B \times C} \qquad (4\text{-}1)$$

where

S = surface area of site
A = quantity of waste (mass per year)
B = application rate (mass per surface area per application)
C = frequency of application (times per year)

There are difficulties in compiling data for Equation 4-1. Application rates may not be known, and there is insufficient information at this time to estimate average application rates for many types of waste. Annual land treatment application rates (equivalent to B x C in Equation 4-1) identified in the literature reviewed in this study, not including the results of the OSW survey (USEPA 1983a), are given in Table 28. A better source of generic data might be the OSW survey (USEPA 1983a); typical annual waste application rates for the land treatment facilities considered representative of the wastes of interest in an exposure assessment can be compiled from the survey data. The lowest economically feasible application rate is 10 kkg/ha/yr (USEPA 1979b); this may be taken as a lower limit in the absence of other data. It may also be difficult to supply a value for "quantity of waste." Application rates are sometimes expressed in terms of total liquid volume; to fit in Equation 4-1, the quantity of waste must be expressed in units compatible with the units used for the application rate. Ideally, total waste stream volume and chemical concentration will be supplied by Stage III estimates, from which the chemical loading (in terms of mass) can be calculated. To further complicate estimations, sludge quantity may be expressed as either wet or dry weight, making direct comparison impossible if the solids content is not known. The solids content of sludge as applied appears to average about 5 percent to 7 percent, but may be as high as 20 percent (Berkowitz et al. 1980, Phung et al. 1978, Ross and Phung 1978). Sludge that has previously been stored in an evaporation basin will have a higher solids content.

The frequency of application is also highly variable, ranging from several times daily for municipal wastewater to once every few years for certain types of waste (USEPA 1983a). There appears to be no published information on which to base reliable estimates of this parameter, and the confidence level for any assumptions made is low.

The model input parameters of surface area and pollutant loading are closely interrelated. An accurate estimate of pollutant loading requires reliable information of the application methods used, in addition to accurate estimates of the waste application rate. Wastewaters are not usually plowed into the ground, but sludges may be plowed or injected to a depth ranging from a few centimeters to 60 cm (Berkowitz et al. 1980). When wastes are incorporated into the soil, the depth of incorporation may be taken as the upper soil zone for a model such as SESOIL, and the loading expressed as the pollutant concentration in that zone. If waste is applied without

Table 28. Annual Land Treatment Application Rates[a]

Waste stream	kkg/ha
Leather manufacturing wastes	800
Municipal/industrial wastewater treatment sludge	140–230[b]
Plastics manufacturing	50–70
Petroleum refining	
Oily wastes and drilling muds	9,500–15,000
API separator sludge	2,000

[a] Figures based on one or a few observations; not a statistically representative sample.

[b] Reported application rates range as low as 1 kkg/ha (USEPA 1980g).

Source: Berkowitz et al. 1980, Phung et al. 1978, Wetherold et al. 1981, Culp 1979.

incorporation, the infiltration rate into the soil must be specified. This may not be known, and will be a significant data gap. The depth of waste incorporation into the soil will also be needed if pollutant loading is to be estimated from monitoring data concentration in soil rather than from known waste application rates.

In the case of multiple applications to the same surface within a year, the timing of the repeat applications must be known to estimate total environmental releases accurately. This information can be obtained only by direct contact with the waste generator or disposal site manager. If it is not available, it will be a significant data gap.

4.1.6 Monitoring

Monitoring data for chemical substances released from land treatment sites are generally not available in readily accessible (i.e., computerized) form. There are a few published studies that assess environmental releases from land treatment, notably the previously mentioned technical resource document on hazardous waste land treatment (USEPA 1983a) and Wetherold et al. (1981). Hazardous waste land treatment sites have to be monitored under the RCRA technical land disposal regulations published in interim final form in 1982 (USEPA 1982c); however, this monitoring data will be accessible only by manual retrieval from EPA Regional offices. Additional monitoring data may be available from applicable state agencies.

4.2 Allocating Waste Streams to Land Treatment Sites - Stage IV Decision Tree

In this stage the user will attempt to enumerate the specific land treatment sites that will receive the waste and the amounts treated at each wastesite. In practice this will be difficult for many land treatment sites because of the paucity of site-specific data. There are methods of estimating the amounts treated per site, however, in the absence of site-specific information, which are presented in the decision tree. The first step in the decision tree is to narrow down the possible land treatment sites to those that are likely candidates for the waste. This is done by considering various waste categories separately. Then the quantity of waste tested is estimated for each site using all available site-specific and generic information.

Step 1. Identify and list the land treatment facilities that are probable candidates for disposal of the waste of interest.

a. Hazardous wastes. Examine the summary survey data from USEPA 1983a presented in Figure E-1 and Tables E-4 and E-5 in Appendix E of this report to identify land treatment sites in the geographic area of interest that potentially treat the waste stream of interest. Be sure to examine the sites listed under SIC code 49 (for commercial waste disposal facilities) in addition to the sites listed under the industrial SIC code of waste generator. Consult the site-specific survey data (Table 2 in Appendix A of USEPA 1983a) for additional information on candidate sites, if any. This information may be supplemented with a Hazardous Waste Data Management System (HWDMS) retrieval (see Section 2.3.3(4) and Exhibit D-1 in Appendix D of this report). Printouts available at the EPA Office of Solid Waste (OSW) list all hazardous waste land treatment facilities within a given area and their capacities (arranged by zip code and waste facility identification number).

b. Nonhazardous industrial waste. Contact the applicable state solid waste agency (see Table D-3 in Appendix D). Most states will supply inventories of waste disposal sites (often incomplete or limited to permitted sites). Unfortunately, few states regulate land spreading of nonhazardous materials, and such facilities are rarely included in state inventories. In addition, consider the possibility that the waste of interest is disposed of in an on-site hazardous waste land treatment facility identified in Step 1.a, above. If no information is available, proceed to Step 2.b.

c. POTW wastewaters and sludges. It may not be possible to determine the location of off-site land treatment facilities for POTW sludge, since many such sites are privately owned farms using the sludge as fertilizer for crops. Even publicly or commercially owned and operated POTW sludge landspreading facilities may not be listed in state-supplied inventory lists. Contacting POTWs that are known to land treat wastewaters and sludges (from the Needs Survey data base, see Sections 2.3.3(3) and 6, and Exhibit H-1 in Appendix H) may provide information on the locations of individual sites. If no information is available, see Step 2.b.

Step 2. **Estimate the amount of waste disposed of at each facility (in mass or volume per year).**

a. References already consulted for Stage III may have provided information on the percentage of the waste stream that is disposed of on- and off-site. For on-site industrial land treatment facilities (for hazardous or nonhazardous waste) identified in Steps 1.a or 1.b above, assume that the total quantity of waste generated on-site is disposed of on-site.

In cases where the industrial waste is likely to be disposed of at commercial land treatment facilities identified in Steps 1.a or 1.b, assume that the total quantity of waste generated by a given source is disposed of at the nearest commercial facility. The quantity of POTW wastewater applied to land at a given POTW will be given by the Needs Survey data base retrieval (see Step 1.c). The quantity of sludge applied to land at a given POTW can be estimated from sludge generation factors provided in Table 34 in Section 6. (The quantity of sludge generated is one output of Stage V for POTWs, Section 6.3.)

b. If data for Steps 1.b or 1.c and/or Step 2.a are not available, proceed as follows. Consult the Needs Survey data retrieval (Exhibit H-1 in Appendix H) to find out whether significant amounts of local sludge are known to be dried and shipped out of the area; if this is the case, it cannot be tracked further. If this is not the case, note that the cost of hauling makes it economically infeasible for nonhazardous sludge to be transported in the wet state very far from the site of generation. Therefore, it can be assumed that all of the waste is landspread close to the point of origin, and Stage V environmental release estimates can be based upon generalized climatological, soil, and geological data for the county.

4.3 Estimating Environmental Releases from Land Treatment - Stage V Decision Tree

In Stage V, environmental releases from land treatment sites in the study area will be estimated using a mathematical model such as PRZM or SESOIL. In cases where there is adequate site-specific information, the model can be run for each site using the appropriate input parameters. In many exposure assessments, however, many parameters will have to be estimated using methods presented in Section 4.1, and below. In such cases one or more model land treatment sites representative of the land treatment sites of interest can be created and used in conjunction with available land treatment site population information.

Step 1. Select an appropriate model for estimating environmental releases.

Environmental releases to air, groundwater, and surface water will be calculated using a model such as PRZM or SESOIL. For nationwide or broad regional environmental releases estimates, consult Section 3.1.6 in addition to the following steps.

Step 2. Identify input requirements.

The following types of data will probably be required for any relevant model:

- Climatological data
- Soil data
- Chemical data
- Geometric, application-specific data

Climatological and soil data are available from standard data sources as described in Section 3.1.4. Chemical information is available from standard reference manuals. Geometric application-related and application-specific information may be more difficult to obtain. As stated previously, the effort in this report focused on developing a few of the previously undeveloped and difficult-to-acquire parameters that are amenable to generic data. See Step 3 for suggestions on estimating the following parameters:

- Groundwater level (Step 3.a)
- Surface area of the site (Step 3.b)
- Pollutant loading (Step 3.c)
- Depths of soil zones (Step 3.d).

Step 3. Estimate relevant application-related and application-specific parameters, wherever appropriate.

a. Depth to groundwater can be determined from statewide computerized data bases when these exist; see Section 3.1.4. In the absence of such data, an arbitrary value (or set of limiting values) can be selected on the basis of the Surface Impoundment Assessment (SIA) data base, soil maps, wetland distribution data for the subject state (see Section 3.1.4), or other general references.

b. Surface area of the site may be available from the OSW Survey (USEPA 1983e), an HWDMS retrieval, or information in state solid waste agency files for hazardous waste land treatment sites. See Section 4.1.5 for a detailed discussion of these sources of information. If site-specific data on surface area are not available, determine whether data are available to estimate surface area using Equation 4-1 (Section 4.1.5). If this is not possible, consider using the median surface area for hazardous waste sites in the U.S. 5.5 ha (13.5 acres), or consider computing the median size for the region or industry of interest in the assessment, using the data in Table 2, of Appendix A of USEPA 1983a.

The approach discussed above is also recommended for land treatment sites receiving nonhazardous wastes.

The recommended approach for estimating the surface area of land treatment sites handling POTW wastewater, in the absence of site-specific data, is to multiply the facility capacity (mgd) by a value within the lower and upper limits of the range of application rates reported in Section 4.1 x .4 (40-240 ha/mgd). The surface area of sites receiving POTW sludges can be estimated in a similar manner, using the quantity of sludge generated (from Stage V of the POTW analysis or Table 34; Section 6) and the estimated application rate (140 - 230 kkg/ha, see Table 28 in Section 4.1.5) in Equation 4-1 (see Section 4.1.5).

c. Pollutant loading (which will be based on the Stage IV estimate) can be expressed in several ways, depending on the nature of the disposal operation. For land treatment, it can generally be assumed that the pollutant is well-mixed into the soil, and pollutant loading can be expressed in terms of mass/area. The mass/area can be estimated using available information on waste application rates, as discussed in Section 4.1.5. If input data are measured concentrations in the soil at a land treatment site, then the area and depth of waste incorporation (see Step 3.d) can be used in conjunction with the chemical concentration to calculate pollutant mass.

d. Depth of soil zones will be determined using the same references that were mentioned for landfills in Section 3.1.4(4)(b), with the exception of the layer of waste incorporation. Wastes may be plowed or injected to a depth ranging from a few centimeters to 60 centimeters. The layer of incorporation will usually constitute the upper unsaturated soil layer.

Given the foregoing limitations, reliable environmental releases estimates may not be possible. If sufficient data have been compiled, proceed to Step 4; if not, proceed to Step 5.

Step 4. Using the model of choice, estimate environmental releases from each site receiving the waste; the chemical concentration in each soil layer can also be estimated if desired.

The output of this step will be the following:

- Flux or mass/area of subject chemical entering groundwater after the modeled period of time.

- Flux or mass/area of subject chemical volatilizing from the upper soil layer to the atmosphere after the modeled period of time.

- Concentration and mass of the subject chemical in each soil layer after the modeled period of time.

- Mass/area of the subject chemical lost due to surface runoff.

Step 5. If monitoring data are available, compare these with predicted concentrations. If estimated concentrations do not correlate with measured values, use best judgment to evaluate the discrepancy. If the input data are insufficient to use a model, monitoring data (if available) may be the only available means of estimating environmental releases. Estimated environmental releases may be used as input in the analysis of environmental fate and in the final exposure assessment, as discussed in Volumes 2 and 5 of this report.

5. SURFACE IMPOUNDMENTS

This section contains the information that will be the basis for the Stage IV and Stage V estimates for treatment, storage, or disposal of wastes in surface impoundments. Surface impoundments receive a large part of the industrial and municipal liquid wastes generated in the U.S. Considerable site-specific information on impoundments is available; however, estimating releases is difficult because of uncertainty in the amounts of wastes in impoundments and the movement of pollutants into and through the groundwater. A discussion of general information on surface impoundments is presented in Section 5.1. This text is the basis for the Stage IV and Stage V decision trees given in Sections 5.2 and 5.3.

5.1 Background Information

A surface impoundment is a natural topographic depression, man-made excavation, or diked area formed primarily of earthen materials designed to hold liquid wastes or wastes containing free liquids. Impoundments may serve the purpose of treatment, storage, or disposal of liquid wastes, and include holding, storage, settling, and aeration pits, ponds, and lagoons. Depending on their design and purpose, surface impoundments may lose liquids by one or more of the following processes: discharge to surface waters, evaporation, and infiltration/percolation. Impoundments which do not discharge to surface waters are called nondischarging impoundments even though losses occur through seepage and volatilization.

A very common type of impoundment is the settling pond, which is used to separate solids from liquids with or without the addition of chemicals to accelerate coagulation and precipitation. Many settling ponds are periodically dredged to restore them to original capacity. Other impoundments are designed specifically to permit seepage into the underlying aquifer. Impoundments that are not designed for seepage may serve as holding or evaporation ponds and are sometimes lined. See USEPA 1978 for a comprehensive description of uses and designs of impoundments in the U.S.

The size of impoundments varies from a few tenths of an acre to hundreds of acres, and depths vary from 0.6 m (2 feet) to more than 9 m (30 feet) below the land surface. Depending on the function, impoundments may be operated individually or may be interconnected so that flow moves from one impoundment to another (Acurex 1980).

The EPA classifies surface impoundments into one of five categories, depending on the origin and the type of wastes: municipal (i.e., water treatment, municipal sanitary landfill, and sewage treatment), industrial, agricultural, mining, and oil and gas brine pits. Municipal sanitary landfill impoundments, sewage treatment plants, and industrial impoundments will generally be of greatest interest because these are the types of facilities that are most likely to receive toxic wastes subject to regulation under TSCA; only the data pertaining to these types will be presented here. Fortunately, more information is available for these sites than for other types of impoundments. However, the procedures developed here could also be applied to agricultural, mining, oil and gas, and water treatment impoundments. Table 29 presents a summary of the estimated number of active impoundments of each category.

Most of the readily available information on surface impoundments comes from state agencies and the Surface Impoundment Assessment (SIA) conducted by the EPA Office of Drinking Water pursuant to Section 1422(b)(3)(c) of the Safe Drinking Water Act. The culmination of this effort is several preliminary summary reports (Geraghty and Miller 1978, Silka and Swearingen 1978, USEPA 1980e) and a computerized data base containing data on the numbers, locations, and potential effects on groundwater of impoundments in the U.S., using a rating system described in Silka and Swearingen (1978). Because of funding limitations, the SIA compiled data for only 80% of the industrial sites, 55% of the sewage treatment sites, and 83% of the municipal sanitary landfill impoundment sites nationwide (see Table 29); therefore, site-specific information is not available for many impoundments. Furthermore, since the SIA was based on unverified secondary sources of data, it will be suitable as source information only for large-scale exposure assessments where errors in or absence of site-specific data will not significantly skew the overall results. Some of the information in the SIA is confidential; therefore, retrievals may not give the owner or name of some facilities. Obviously, additional site-specific data would be necessary for exposure assessments where site-specific estimates of chemical releases are required. Other useful sources of information on surface impoundments include the Needs Survey (Exhibit H-1 in Appendix H) and the references on hazardous and industrial waste disposal mentioned in Sections 2.3.3(4) and 2.3.3(5) and documented in Appendix C and Table D-5 of Appendix D.

5.1.1 Types of Impoundments

Municipal sanitary, sewage treatment, and industrial surface impoundments serve different purposes and receive different kinds of waste streams. A brief summary of relevant features of each of these categories follows:

(1) Municipal sanitary landfill impoundments. The SIA located 179 sites containing approximately 446 impoundments. Of the located sites, 149 were assessed. No description of the impoundments in this category was given in the reports published to date, but it is assumed that these

Table 29. Summary Statistics for Active Surface Impoundment Sites Located in the SIA

Category	Number of located sites	Number of assessed sites	Number of located impoundments[b]
Industrial	10,819	8,193	25,749
Municipal	19,116	10,675	36,179
Agricultural	14,677	6,597	29,167
Mining	7,100[a]	1,448	24,451
Oil and gas brine pits	24,527[a]	3,304	64,951
Other	1,500	327	5,745
TOTAL	77,739	30,544	176,242

[a] The number of mining and oil and gas brine pit sites is not necessarily related to actual ownership and may be different than the actual number of legal sites. The number of located impoundments would be a closer approximation for these two categories.

[b] Some sites have more than one surface impoundment.

Source: USEPA 1980e.

sites generally receive partially dehydrated sludges from POTWs. Only 29.5% of the assessed sites had liners; the types of liners used are given in Table 30. Based on an EPA estimate, the typical size of this type of impoundment is about 1 ha (2.5 acres) (USEPA 1979b).

(2) Municipal sewage treatment impoundments. This type of impoundment may be used to treat, store, and dispose of wastewater as well as sewage sludge. Based on the Needs Survey (see Exhibit H-1 in Appendix H), the SIA located 18,189 sewage treatment plants with a total of 34,356 impoundments. Of the located sites, 10,043 were assessed, and 22.8% of the assessed impoundments were lined (Table 30) (USEPA 1980e).

A variety of types of surface impoundments are associated with the storage, treatment, and disposal of wastewaters. These impoundments may be lined or unlined and may represent minor or major components of large treatment and waste disposal systems; they may also be the sole component. In primary treatment systems, impoundments may be used for temporary storage, settling or disposal of wastewater by percolation and evaporation. In conventional secondary treatment plants, impoundments may be used only for storage and settling; impoundments may be the principal components of systems that consist mainly of anaerobic and aerobic waste-stabilization ponds. Another type of impoundment used in secondary treatment is the temporary holding or storage pond for disposal of effluent after secondary treatment. In some tertiary treatment plants, effluents are passed through shallow polishing ponds. In many wastewater treatment systems, wastewater is ultimately discharged to streams rather than disposed of by evaporation or seepage (USEPA 1978).

Impoundments at sewage treatment facilities are also used for the treatment, storage, and disposal of municipal sewage sludge. They are commonly used for temporary storage of sludge prior to ultimate disposal, for sludge stabilization prior to land application, or as permanent disposal for liquid, dewatered, heat-dried or composted sludge (USEPA 1980a). Shallow rectangular impoundments with permeable sand bottoms are sometimes used for drying municipal sewage sludge. These "drying beds" may or may not have underdrains for leachate control. Impoundments that receive partly dehydrated sludge are usually covered and abandoned after being filled (USEPA 1978). Approximately 11% of the sewage sludge produced in 1978 was disposed of in such lagoons (USEPA 1980f). Table 6 in Section 2.3.3(2) presents more recent estimates on sewage treatment impoundments.

The size of sewage treatment impoundments varies, but one EPA publication assumed that the typical area is 1 ha (2.5 acres) (USEPA 1979b). Oxidation ponds are generally 0.9 to 2.4 m deep, aerated lagoons are 2.4 to 4.6 m deep, and anaerobic lagoon systems are 3.6 to 5.2 m deep (USEPA 1978).

Table 30. Liner Data, Municipal Impoundment Sites

	SIC code	Total sites liner data	Total unlined	Liner 2-3-4-15	Liner 5-6-7	Membrane liner 8-14	Percent lined	Percent unlined
Water supply	4941	442	350	81	6	5	20.9	79.1
Refuse system	4953	139	98	27	4	9	29.5	70.1
Sewage system	4952	7,282	5,624	1,416	83	158	22.8	77.2
Subtotal		7,863	6,072	1,524	93	172	22.8	77.2

2 = Clay
3 = Bentonite, modified
4 = Chemically modified clay
5 = Concrete
6 = Asphalt
7 = Metal
8 = Polyethylene
9 = Plasticized PVC
10 = Butyl rubber sheeting
11 = Hypalon sheeting
12 = Ethylene propylene
13 = Chlorinated polyethylene
14 = Other membrane
15 = Other

Source: USEPA 1980e.

(3) Industrial impoundments. Many industries treat, store, or dispose of liquid wastes in impoundments. The design and function of industrial impoundments varies widely by industry. Industrial impoundments are typically used for evaporation, aeration, oxidation, recycling, infiltration, stabilization, settling, disposal, and storage. Stabilization ponds are very common waste treatment systems at industrial plants. In some plants auxiliary ponds serve for polishing (i.e., final treatment) and temporary retention of effluents from conventional activated sludge systems before discharge to streams. Ponds may also receive scrubber water and ash residues (See Section 2.3.3(1) and USEPA 1978).

The size of industrial impoundments varies widely. One EPA document assumed that 95% of all industrial facilities are approximately 1 ha (2.5 acres), the remaining 5% being 20 ha (50 acres) (USEPA 1979b). These figures, together with the range of depths presented in the description of municipal sewage treatment impoundments form the basis for design estimates when site-specific data are not available or desirable.

The SIA located 10,819 industrial sites containing a total of 25,749 impoundments. Of the 8,243 assessed sites, only 27.6% were lined (USEPA 1980e). See Tables 31 and 32 for the breakdown of surface impoundment populations and liner characteristics by SIC Code. A recent compilation of HWDMS application data (Table D-7 in Appendix D) indicates that nationwide there are 1,366 facilities that treat or store hazardous wastes in surface impoundments and 360 that dispose of hazardous wastes by surface impoundments.

5.1.2 Environmental Releases from Surface Impoundments

Chemical substances treated, stored, or disposed of in waste impoundments may be released to air, surface water, and groundwater over time. Releases to air may occur via volatilization of organic gases and fugitive dust. Surface waters may be contaminated by permitted effluents, by sudden releases when dikes are breached or lagoons are washed out during periods of high surface runoff, or by leached contaminants. Finally, surface impoundments without properly designed containment and leachate collection systems may cause contamination of groundwater resulting in human exposure through the consumption of well water or through seepage of groundwater into basements and subsequent volatilization of toxic substances (Acurex 1980). The information resources reviewed in the course of developing this methodology did not include any models designed specifically to estimate environmental releases from surface impoundments. See Section 3.1.3 for a general discussion on predicting environmental releases from land disposal sites.

Table 31. Distribution of Industrial Impoundment Sites by SIC Code

SIC Code	Type facility	Located sites	Located impoundments	Assessed sites
20	Food	2,162	5,160	1,708
21	Tobacco	6	11	5
22	Textile mills	268	536	210
23	Apparel	15	13	10
24	Lumber and wood	373	781	294
25	Furniture and fixtures	23	35	20
26	Paper and allied products	421	1,349	288
27	Printing and publishing	18	24	15
28	Chemical and allied products	1,514	4,577	1,276
29	Petroleum and allied products	696	1,984	537
30	Rubber and misc. plastics	156	252	129
31	Leather products	34	104	31
32	Stone, clay and glass products	723	1,343	630
33	Primary metals	599	1,480	444
34	Fabricated metals	686	1,416	513
35	Machinery	174	294	141
36	Electric and electronic	210	391	177
37	Transportation equipment	217	510	152
38	Instruments	47	92	36
39	Misc. manufacturing	235	359	120
40-47	Transportation	320	516	238
491	Power plants	593	1,671	301
492	Gas production and dist.	250	543	62
493	Combination elec/gas	39	81	36
496	Steam supply	17	35	13
4953	Industrial refuse sites	199	602	161
517	Petroleum bulk terminal	65	141	46
554	Service stations	50	65	44
721	Cleaning establishments	261	381	129
7542	Car washes	59	72	48
1389	Oil field services	276	764	96
07	Agricultural services	93	167	83
TOTAL		10,819	25,749	8,243

Source: USEPA 1980e.

Table 32. Liner Data Industrial Impoundment Sites

SIC Code[a]	Total Sites Liner Data	Total Unlined	Liner[b] 2-3-4-15	Liner[b] 5-6-7	Membrane Liner[b] 8-14	Percent lined	Percent unlined
20	1,337	981	299	24	33	26.7	73.3
21	4	4	0	0	0	0.0	100.0
22	151	112	24	4	11	25.9	74.1
23	6	5	1	0	0	16.7	83.3
24	257	165	84	6	2	35.8	64.2
25	14	10	3	1	0	28.6	71.4
26	253	153	75	3	22	39.6	60.4
27	12	11	0	1	0	8.4	91.6
28	1,012	647	222	44	99	36.1	63.9
29	446	319	103	18	6	28.5	71.5
30	114	91	12	6	5	20.2	79.8
31	27	22	3	1	1	18.6	81.4
32	498	386	80	24	8	22.5	77.5
33	402	275	85	17	25	31.6	68.4
34	453	357	62	12	22	21.2	78.8
35	113	75	24	6	8	33.7	66.3
36	154	112	20	8	14	27.3	72.7
37	131	98	22	5	6	25.2	74.8
38	30	22	3	1	4	26.7	73.3
39	105	89	11	3	2	15.3	84.7
40-47	187	129	43	9	6	31.1	68.9
491	375	243	102	11	19	35.2	64.8
492	49	32	9	3	5	34.7	65.3
493	34	26	7	0	1	23.6	76.4
496	13	11	1	1	0	15.4	84.6
4953	135	90	33	6	6	33.4	66.6
517	41	33	8	0	0	19.6	80.4
554	44	41	2	1	0	6.9	93.1
721	109	105	3	0	1	3.7	96.3
7542	39	35	3	1	0	10.3	89.7
1389	92	73	10	3	6	20.7	79.3
07	78	62	12	0	4	20.6	79.4
TOTAL	7,715	4,814	1,366	219	316	27.6	72.4

[a] See Table 31 for key to SIC codes.

[b] See Table 30 for key to liner types.

Source: USEPA 1980e.

5.2 Allocating Waste Streams to Surface Impoundments - Stage IV Decision Tree

In this stage, the user will evaluate available information on the disposal practices of the subject waste generators, the types of impoundments in the study area, and the waste characteristics in order to enumerate the impoundments that are likely to receive the subject waste stream. The waste stream will be allocated to individual sites using criteria tailored to the source and nature of the waste. The confidence in these estimates will vary depending on the source of the waste and the types of impoundment.

Step 1. **Determine whether disposal of the subject waste stream will be limited to certain types of surface impoundments.**

As discussed in the introduction to surface impoundments, a variety of impoundment designs are in use at both municipal and industrial sites. Because of data limitations, it was not possible to develop a rule for estimating the types of impoundments that can be found at a given site in the absence of site-specific information. Therefore, this information will have to be obtained from computer retrievals of the SIA, Needs Survey, and HWDMS data bases, as described below. These data bases can be used as a source of both generic and site-specific information on impoundment type.

Step 2. **If applicable, determine the proportional distribution of the subject waste stream between on-site and off-site facilities.**

This knowledge will be helpful in Step 3, when identifying individual impoundments that are probable candidates for disposal of the wastes.

The degree of on-site versus off-site disposal in impoundments varies depending on the type of waste. Separate procedures for estimating on- versus off-site disposal are given below for wastewaters, POTW sludges, hazardous waste, nonhazardous industrial solid waste, and incinerator residue. In general, however, off-site versus on-site disposal in surface impoundments can be estimated in one of two ways: (1) using waste-specific or industry-specific generic information and (2) using site-specific information.

a. Wastewaters. All municipal and industrial wastewaters treated at POTWs that use impoundments for treatment, storage, and disposal are by definition disposed of off-site. Therefore, the percentage of wastewaters treated off-site will already have been determined in Stage III. It will be more difficult to determine the extent to which surface impoundments are involved in the treatment of the industrial wastewaters that are treated on-site because this information is not always available. The only direct source of information on impoundments associated with industrial wastewater treatment is the Surface Impoundment Assessment data base (SIA). As stated previously, however, this data base is not complete.

b. POTW sludges. Surface impoundments used for the storage or disposal of POTW sludges will generally be located at the POTW facility.

c. Hazardous wastes. The percentage of the waste treated, stored, or disposed of in surface impoundments on-site can be very roughly estimated by examining waste-specific or industry-specific disposal patterns reported in available documents listed in Section 2.3.3(4). (See Appendix C and Table D-5 in Appendix D for examples of the kind of information available in these documents.) Table 27 in Section 4, compiled from USEPA 1980b, suggests that actual disposal of hazardous wastes in off-site facilities may be restricted to only 11 facilities nationwide, all of which occur in EPA Regions IV, VI, IX, or X. These facilities handle only 1.3% of the hazardous wastes generated. Industry-specific information contained in other documents, presented in Appendix C and Table D-5 in Appendix D, can be used in conjunction with Table 27 to decide whether it is likely that the waste will be disposed of in off-site impoundments. For instance, if Table 27 indicates that there is no commercial hazardous waste facility using a lagoon for treatment, storage, or disposal in the vicinity of a manufacturing plant producing a waste that is usually disposed of via surface impoundments, it can be assumed that the waste is handled on-site. Other sources of this information are the Hazardous Waste Data Management System (HWDMS) (see Section 2.3.3(4) and Exhibit D-1 in Appendix D) and the SIA data base. Retrievals from these data bases can indicate three things: (1) whether there is an impoundment on-site at a given location, (2) what percentage of facilities of a certain type (e.g., manufacturers of organic chemicals) have on-site impoundments, and (3) what percentage of commercial hazardous waste disposal facilities in the area of interest use surface impoundments for treatment, storage, or disposal. The site-specific and generic data derived from these data bases should be used to supplement the above-mentioned documents.

d. Nonhazardous industrial solid wastes. No known sources of compiled information exist on the degree to which this type of waste is disposed of off-site in surface impoundments, except for the inventory of impoundments compiled by Waste Age magazine (see Table 33). Until better data are available, it is suggested that the same data sources be used as for industrial hazardous wastes. The SIA should be particularly helpful because it will generally indicate whether or not an impoundment is located on-site, regardless of whether the facility has filed an application for hazardous waste handling. The SIA may also be useful as a source of generic data if a retrieval is done for the SIC code of interest.

e. Incinerator residue. If impoundments are used for the storage or disposal of incinerator wastes, it can generally be assumed that the impoundment will be located near the site of incineration.

Step 3. **Based on the information in Steps 1 and 2 and available inventories of disposal facilities, identify the impoundments that are probable candidates for disposal of the subject waste. Consider the obvious constraints imposed by the geographic area, the applicable types of impoundments, and the disposal practices of industry for the waste stream of interest.**

All of the information needed for this step will be available through the computer retrievals of the SIA and HWDMS data bases in addition to general documents on industrial disposal practices. Separate decision trees are presented below for each of the different waste categories.

a. Wastewaters. The information compiled for POTWs from the Needs Survey data base (see Sections 2.3.3(3) and 6 and Exhibit H-1 in Appendix H gives some indication of whether surface impoundments are used to treat, store, or dispose of wastewaters based on the treatments used at a given POTW. For instance, the use of stabilization ponds, aerated lagoons, sludge lagoons, air drying lagoons, and seepage lagoons is always associated with surface impoundments. Additional information can be gleaned from knowledge of the wastewater treatment methods used at the POTWs of interest (given in the Needs Survey retrieval). However, the extent to which impoundments are used for storage and in conjunction with types of wastewater treatment other than those listed above is not always clear based on the Needs Survey computer retrieval. For this reason, the Needs Survey data should be supplemented using site-specific data retrieved from the SIA data base for municipal sewage treatment impoundments. Even with the SIA data, however, there will not be site-specific

Table 33. Inventory of Pits, Ponds, and Lagoons from 1981 Waste Age Survey

EPA Region/ State	Number of pits, ponds, and lagoons identified in EPA's SIA[a]	Number of pits, ponds, and lagoons owned and operated by the industry upon whose site they are located[a]
Region #1		
Connecticut	1,200	610
Maine	453 @ 173 sites	177
Massachusetts	1,962	1,962
New Hampshire	-	-
Rhode Island	45	45
Vermont	-	-
Region #2		
New York	-	-
Delaware	-	-
New Jersey	1,027	unknown
Puerto Rico	379	379
Virgin Islands	-	-
Region #3		
District of Columbia	0	0
Maryland	-	-
Pennsylvania	33,401	1,645(+ 19,702 @ oil & gas wells)
Virginia	-	-
West Virginia	-	-
Region #4		
Alabama	-	-
Florida	5,681	5,681
Georgia	-	-
Kentucky	340	-
Mississippi	3,300	3,200
North Carolina	5,717	unknown
South Carolina	-	-
Tennessee	1,500	648
Region #5		
Illinois	8,000	8,000
Indiana	2,688	unknown
Michigan	-	-
Ohio	14,000	1,500
Minnesota	3,365	415 impoundments
Wisconsin	1,717	614

Table 33. Inventory of Pits, Ponds, and Lagoons from 1981 Waste Age Survey (continued)

EPA Region/ State	Number of pits, ponds, and lagoons identified in EPA's SIA[a]	Number of pits, ponds, and lagoons owned and operated by the industry upon whose site they are located[a]
Region #6		
Arkansas	2,000	unknown
Louisiana	2,881	916 Ind./101 Mun./1,863 oil/gas
New Mexico	2,101	702 + 15,761
Texas	3,842	3,458
Oklahoma	4,524	466
Region #7		
Iowa	-	-
Kansas	3,398	263
Missouri	-	-
Nebraska	600	100
Region #8		
Colorado	1,900	unknown
Montana	-	-
Utah	660	unknown
Wyoming	-	-
North Dakota	-	-
South Dakota	-	-
Region #9		
Arizona	552	unknown
California	-	-
Hawaii	-	-
Nevada	923	unknown
Region #10		
Alaska	-	-
Idaho	-	-
Oregon	714	714
Washington	1,047	466
Guam	102	102
TOTALS	109,839	69,490

[a] Blank denotes information not available at the time of the survey. The SIA data base has a more up-to-date listing.

Source: Anon. 1981c, Waste Age, Land Disposal Survey.

data for all surface impoundments because not all municipal impoundments were included in the SIA. Furthermore, the SIA assessments do not always indicate the type of lagoon. Therefore, it is recommended that the investigator consider using Needs survey and SIA retrievals to develop generic data on the type of impoundments likely to be associated with various types of wastewater treatment as described below. If fairly accurate generic data are desired, the municipal impoundment data from the SIA can be aggregated according to treatment (available through the Needs Survey retrieval). For example, the SIA municipal impoundment data for all secondary POTW plants using activated sludge (as indicated by the Needs Survey data) can be analyzed to extract generic data on the average number of impoundments per site, the average surface area of the impoundments, and the type of influent (primary, secondary, sludge, etc.). These generic data can be used for POTW plants for which the site-specific impoundment data in the SIA are not sufficient to characterize the impoundments. The level of detail and accuracy required by the exposure assessment will dictate whether the time spent comparing the SIA and Needs Survey information is justifiable.

b. POTW sludge. The Needs Survey retrieval sometimes provides information on whether a given POTW disposes of its sludge on- or off-site and usually lists the treatment/disposal method used. The utility of the Needs Survey data base in determining sludge-handling practices at POTWs was discussed in Section 2.3.3(2). Use the Needs Survey retrieval to compile a list of POTWs that appear to use impoundments in the sludge handling process. The fact that the Needs Survey does not always indicate whether the POTW sends its sludge to another facility for handling does not constitute a major data gap, because most POTWs that treat wastewater on-site also have a means of handling their own sludge (USEPA 1981e).

c. Hazardous wastes. The determination of surface impoundments likely to receive the waste of interest will be based on the site-specific information in the SIA and HWDMS data bases in addition to the general information on industry-wide disposal practices assembled in Stage III, and the information compiled in Step 2. First, assemble all site-specific information retrieved from the HWDMS and the SIA data bases (this will already have been done in Step 2). Check to see which of the sites of interest have on-site surface impoundments and which off-site commercial disposal facilities use surface impoundments for treatment, storage, or disposal. Evaluate the information on disposal practices for wastes similar to the subject waste (see Table 9 in Section 2) and other information listed in Appendix C and Table D-5 in Appendix D. From this material, compile a list of the sites which have surface impoundments that are likely candidates for receiving the waste.

d. Nonhazardous industrial solid wastes. As stated in Step 2, there are no known documents that contain useful information on the nonhazardous industrial waste practices of industries. Therefore, the investigator should rely heavily on the SIA data base for information on which sites might use on-site impoundments for treatment, storage, or disposal of wastes. This information should be supplemented with the generic information on industrial waste practices presented in Stage III (and Appendix C and Table D-5 in Appendix D), under the untested assumption that industries will treat similar wastes in similar ways, regardless of whether the wastes are hazardous. Some individual judgment will be necessary in deciding which off-site impoundments are likely candidates for the subject waste.

A retrieval from the SIA data base of all industrial impoundments in the area of interest may provide the investigator with some clues as to which have off-site facilities. For example, the name of the owner and auxiliary information on the types of wastes handled may indicate whether any commercial disposal facilities in the area operate impoundments. Assuming that hazardous waste practices are similar to nonhazardous waste practices, it is unlikely that off-site disposal in impoundments is very common. An exception to the rule may be off-site disposal of nonhazardous industrial wastewater treatment sludges via off-site POTW sludge handling facilities. This is not a widespread practice, however; currently only five POTWs, located in California, Delaware, Louisiana, and Texas, handle such sludges (USEPA 1981e). A Needs Survey data base retrieval could provide site-specific data on these facilities, if required.

e. Incinerator residue. See Section 2.3.3(1) for information on disposal of ash in lagoons. If ash is disposed of in lagoons (which may not be readily determined), assume that the lagoon will be at the site of the incinerator. The incinerators that have on-site lagoons may possibly be identified by comparing the data from the SIA data base retrieval with incinerator inventories (see Appendix I, Tables I-2, and I-3). Assume that the incinerators with on-site lagoons use them for ash disposal.

Step 4. Quantify the amount of the subject waste handled by each disposal site identified in Step 3.

Check to see whether there is information on the capacity and current operating characteristics (e.g., types of wastes handled) for the sites listed in Step 3. If so, use this information in conjunction with available information on the disposal practices of the source(s) of the waste disposed of at each facility to allocate wastes to each site. If not, allocate the waste according to some other method (e.g., equal distribution to all candidate sites). The output from Stage IV for assessments requiring site-specific estimates of environmental releases will be a list of candidate sites and the amounts of the subject waste disposed of at each site. The primary sources of data for this step are the SIA, HWDMS, and Needs Survey data bases. Additional useful generic information can be derived from previously cited documents pertaining to surface impoundments. Separate discussions on how to allocate amounts of waste to individual sites are presented below for wastewaters, POTW sludges, hazardous wastes, nonhazardous wastes, and incinerator ash.

a. Wastewaters. For all of the municipal impoundments listed in Step 3, one can obtain the current POTW plant flow from the Needs survey data base retrieval. This information, coupled with any available site-specific data relating to capacity given in the SIA, will provide a basis for estimating the maximum amount of waste treated, stored, or disposed of at the impoundment of interest. See Section 6.2 to find out how to estimate how much wastewater is treated at a given POTW. This represents the maximum amount of the waste that might be treated, stored, or disposed of in the POTW surface impoundments. Based on additional generic or site-specific data retrieved from the SIA data base, this maximum estimate can in some cases be refined to reflect the amount that is really being handled by the surface impoundments. In most cases, however, the investigator will have to assume that all of the wastewater treated at the POTW will pass through or be disposed of in the impoundments.

b. POTW sludge. Using the list of POTWs that are likely candidates for the treatment, storage, or disposal of sludge in surface impoundments (Step 3) in conjunction with site-specific information from the SIA data base, the percentage of the waste that goes into impoundments can be estimated, as described below. The Needs Survey data will indicate which sludge disposal practices are used and thus will provide information on the type of impoundments used and whether they are for treatment, storage, or ultimate disposal. The site-specific SIA data will sometimes augment the Needs Survey information by giving the number of surface impoundments, the type of waste (e.g., sludge, wastewaters), and the purpose of the impoundment (whether it is for treatment, storage, or disposal). If the site-specific SIA data are insufficient to determine the number of impoundments involved in sludge handling, use individual judgment based on the Needs Survey data to estimate how much of the sludge is handled in surface impoundments, and whether the impoundments are used for treatment, storage, or disposal.

c. Hazardous wastes. The allocation of hazardous wastes to individual impoundments will be based largely on data retrieved from the HWDMS data base supplemented by information from the SIA data base. Use the list of probable sites compiled in Step 3 as the basis for the allocations. Data from the HWDMS retrieval will indicate which plants have on-site impoundments that handle hazardous wastes. Unless competing hazardous waste handling methods are practiced on-site, assume that all of the on-site generated waste is handled in the surface impoundment(s), providing that the capacity of the impoundments (given in the HWDMS retrieval) is sufficient to handle it. In the case where other disposal methods are available on-site (as indicated by the HWDMS retrieval) review the available documents on waste disposal for the industry of interest (see Section 2.3.3(4), the tables in Appendix C and Table D-5 in Appendix D), paying particular attention to the disposal methods commonly used for similar wastes. If some of these methods are also available on-site, then use best judgment to allocate the waste between treatment in surface impoundments and the other waste handling methods.

If any off-site commercial hazardous waste facilities with surface impoundments were listed in Step 3 as probable candidates for receiving the waste, then use best judgment to allocate the waste to the most appropriate site. As stated previously, however, off-site surface impoundments are not often used for handling the hazardous wastes from most industries.

After the initial allocation of subject waste quantities to individual surface impoundments is complete, be sure to evaluate these estimates in light of the original Stage III estimates for all disposal methods, as suggested in Section 2.3.3.

d. Nonhazardous industrial solid waste. Use the list of probable impoundment sites from Step 3. Proceed as for hazardous wastes, except that the SIA rather than the HWDMS will be the major site-specific source of data. Because there will not always be site-specific information on competing treatment/storage/ disposal methods for nonhazardous wastes (unless there are data on landfills, etc., provided by the states), it will be more difficult to evaluate the likelihood that the subject waste is handled on-site by methods other than surface impoundments. Considerable individual judgment will be required in this step. In general, however, assume that all of the waste generated on-site is handled by identified on-site impoundments if the subject waste is similar to wastes frequently handled by this method.

e. Incinerator residue. Based on the information presented in Section 2.3.3(1), it is reasonable to assume that all of the incinerator residue generated on-site is disposed of on-site. Therefore, in the absence of information to the contrary, assume that incinerator sites with on-site surface impoundments dispose of all of the incinerator residue in the impoundments.

5.3 Estimating Environmental Releases from Surface Impoundments - Stage V Decision Tree

This stage involves the estimation of releases to air, surface waters, and groundwater from surface impoundments. First, the user characterizes the design/operating features of the subject impoundments with respect to parameters that affect releases. Then, these site-specific parameters are used in conjunction with the waste input (from Stage IV) as input parameters in an appropriate model(s) to estimate releases. This study identified no comprehensive models tailored to estimating releases to all environmental media from surface impoundments. For large-scale assessments, the SIA data base can be used to generate generic data on typical or representative sites together with data on the number of facilities. See Volume 1 of this series for a discussion of this approach to exposure assessments.

Step 1. **a. Identify and list the important design and operating characteristics of surface impoundments that affect releases to the environment.**

A number of design factors of surface impoundments affect their ability to release chemical substances to the air, groundwater, and surface waters. The most important of these are listed below.

- Liner. The potential for groundwater contamination is largely a function of the type and condition of liner used (if any). In order to function properly, the liner must be compatible with the impounded wastes and free of defects. Breaks or leaks in liners will obviously result in escape of impounded wastes into the soil beneath the impoundment, increasing the potential for contamination of groundwater.

Currently there are no statistics on the probability of liner leakage as a function of liner type and age. For detailed discussions of the complex relationship between liners, impounded wastes, and seepage, see USEPA (1983b), Stewart (1978), and Acurex (1980).

- Cover. Surface impoundments with covers will generally allow less volatilization than those without covers. Although no statistics were found on the percentage of impoundments with covers, the available literature suggests that the use of covers in active surface impoundments is very rare.

- Surface area. The nature of volatilization and seepage is such that the surface area of the impoundment affects releases; therefore, the larger the area, the greater the emission rate of volatile compounds.

- Thickness of the unsaturated zone. The unsaturated zone is the depth from the base of the impoundment to the water table. The potential for the contamination of groundwater may increase with decreasing thickness of the unsaturated zone, because pollutants attenuate to varying degrees as they migrate down through the unsaturated zone.

- Type of subsoil in the unsaturated zone. This factor is an important determinant of the potential for groundwater contamination because pollutant attenuation depends in part on the characteristics of the soil, including sorption character and permeability.

- Thickness of the saturated zone. This parameter affects the ability of the groundwater to transmit water.

- Type of earth material in the saturated zone. This parameter also affects the ability of the aquifer to transmit groundwater.

- Amount of freeboard (i.e., vertical distance between level of liquid and top of berm or dike) in the sides of the impoundment. An impoundment with considerable freeboard will have a lower probability of flooding onto adjacent areas during periods of heavy precipitation than one with little or no freeboard. The amount of freeboard is also related to the maximum surface area of the impoundment.

- Effluent to surface waters. Obviously, an impoundment that discharges continuously or intermittently to surface waters has the potential to contaminate the receiving stream.

It should be stressed that the preceding list includes only the most important parameters; the interaction of these factors creates a complex problem in predicting releases that has not been solved to date.

b. Determine which of the parameters listed in Step 1.a are known for the sites of interest based on accessible computerized data or other readily available information.

The SIA data base includes some of the relevant parameters on a site-specific basis for those surface impoundments for which a complete assessment was conducted (see Section 5.1). However, when the data base was created, some parameters were grouped into categories for the purpose of rating the sites as to potential for groundwater contamination, and the "raw" data were not included in the data base. Therefore, the data can only be extracted as ranges. The following is a summary of the data (Silka and Swearingen 1978). Refer to Tables G-1 and G-2 in Appendix G for the relation between the rating and the raw data.

- Thickness of the unsaturated zone. This parameter is classified into one of five categories ranging from 1 m to greater than 30 m.
- Earth material for unsaturated zone category. This parameter is classified into one of three categories ranging from material with a permeability of 2 gpd/ft^2 to 0.02 gpd/ft^2.
- Thickness of saturated zone. This parameter is placed in one of three categories ranging from 3 to 30 m.
- Liner. The assessments often include information on whether a liner is present and on the type of liner. Liner types include: clay, modified bentonite, chemically modified clay, concrete, asphalt, metal, polyethylene, plasticized PVC, butyl rubber sheeting, chlorinated polyethylene.
- Size. Another auxiliary parameter that is sometimes included in the site-specific assessments is the size of the impoundment. The information sources reviewed for this methodology were not clear as to whether the size is reported as area, capacity, or depth. Surface areas may be estimated if capacity and depth are known or estimated.

The following parameters are sometimes available in accessible form from sources other than the SIA data base:

- Capacity. For hazardous waste impoundments the capacity will be listed on the RCRA hazardous waste treatment/storage/ disposal (TSD) permit application (see Section 2.3.3(4) and Exhibit D-1 in Appendix D) and will be entered in the HWDMS data base.

- Effluent characteristics. If the surface impoundment has a NPDES permit (see Exhibit H-2 in Appendix H) to discharge into surface waters, the effluent volume may be available in the Industrial Facilities Discharge (IFD) file (see Section 6 and Exhibit H-2 in Appendix H). However, if the facility has other outfalls in addition to the surface impoundment outfalls, it may not be clear from the IFD printout which flow corresponds to the surface impoundments.

c. **Decide which of the parameters listed in Step 1.a but not Step 1.b (i.e., parameters that are useful but not readily available) can be obtained from existing files at regional EPA offices and state solid waste agencies.**

All parameters listed in 1.a are sometimes available from agency files. The RCRA Part B permit application may contain much of the site-specific information related to pollution potential for hazardous waste surface impoundments. However, there are presently no plans for computerization of the information contained in these applications, so these data will generally have to be retrieved manually from the EPA regional offices. Many of the parameters may be included in state permit files, depending on how comprehensive the state's records are. See Section IX of USEPA 1978 for a summary of state policies and regulations regarding surface impoundments.

Step 2. a. **Select the most appropriate model for predicting releases based on design/operating characteristics of the surface impoundments and the characteristics of the impounded wastes.**

The ideal model for predicting environmental releases from surface impoundments would be multimedia and would incorporate the biological, chemical, and physical processes that occur within the impoundment, such as biodegradation and sorption; it would also include provisions for the effect of liners on releases to groundwater was identified in the information resources consulted in developing this volume. No such model, was identified in the information resources consulted to develop this volume, although the SESOIL model developed by Arthur D. Little Inc. for the EPA Office of Toxic Substances is potentially adaptable for this purpose. See Section 3.1.3 of this report and Volume 5 of this methods development series for a more detailed discussion of modeling considerations.

A set of equations for estimating releases to air from surface impoundments is presented in Hwang (1982). These equations consider the following parameters:

- Chemical properties of the impounded substance
- Concentration of the substance
- Surface area of impoundment
- Overall mass transfer coefficient (based on the equilibrium constant, the liquid-phase mass transfer coefficient, and the gas-phase mass transfer coefficient).

This model estimates the release rate in grams per second. The most difficult parameter to estimate when using this model is the concentration, which is not usually available for existing facilities and difficult to estimate accurately in proposed facilities.

b. Determine which site-specific design/operating parameters are required to predict releases from surface impoundments; consider whether there are "default" values for these parameters that can be used in the absence of site-specific data.

Estimating releases from surface impoundments generally requires numerous climatological, soil, chemical-specific, and site-specific data. The following procedures provide guidance on how to acquire data for a few parameters for which generic data have not been previously compiled.

- Surface area of the impoundment (m^2). When site-specific information on the area of the impoundment is not available (either in the SIA or EPA/state files) assume that the average area of most impoundments is 1 ha (2.5 acres). Alternatively, do a retrieval of the SIA data base to obtain representative capacity data for the appropriate type of impoundment (e.g., municipal sewage treatment, industrial, etc.) that can be used as surrogate data. Obviously, if the capacity (volume) and the depth of the impoundment are available on a site-specific basis, the area can be calculated, thus avoiding the need for surrogate values.

- Depth to groundwater (m). As stated previously, this will be roughly available through the rating system for surface impoundments that were included in the SIA data base (see Section 5.1). For those that were included, there are at least two options: (1) Go to the sources of original data recommended in the SIA documentation (USEPA 1978), or (2) retrieve relevant data for other surface impoundments in the vicinity of the site(s) of interest, and use those data to estimate the depth of the unsaturated zone.

- Depth of the upper, middle, and lower soil zones. The data in the SIA are not sufficiently detailed to deduce differences between the various soil layers; therefore, unless site-specific data can be obtained manually from state or EPA files, or from sources mentioned in USEPA (1978), assume a uniform unsaturated soil layer, with no distinguishable upper, middle, or lower soil zones.

- Total volume of impounded liquid wastes. Volume data can be calculated from the depth and surface area on a site-specific basis from the SIA or HWDMS data bases (assume capacity = volume). Alternatively, if resources permit, capacity information could be obtained manually from state or EPA permit files. If no site- specific data are available, use surrogate data obtained by a computer retrieval (SIA or HWDMS) of capacity data for impoundments expected to be similar to the impoundment(s) of interest. As a last resort, calculate volume, assuming that the area is 1 ha (2.5 acres) and that the depth is within the range given below, depending on the type of impoundment (USEPA 1978). If the type of impoundment is not known, one may assume a depth of 3.8 m, which is midway between the lowest and highest values listed.

Aerated lagoon:	2.4-4.6 m
Oxidation pond:	1.9-2.4 m
Anaerobic lagoon:	3.5-5.2 m

- Concentration of subject chemical substance in the impounded liquid (mass/volume). This parameter can be estimated using knowledge of the mass of the chemical substance in the impounded waste (from Stage IV) in conjunction with the total volume of impounded wastes (see above). A simple dilution calculation can be used, as follows (Equation 5-1).

$$C = \frac{M}{V} \tag{5-1}$$

where

C = concentration of subject chemical in impounded waste
M = mass of chemical in impounded waste
V = total volume of impounded waste.

- Pollutant loading in each soil zone (mass/area). This parameter, which will be required by any applicable model, will be based on the concentration of the subject chemical in the impoundment, which will in turn be based on the output of Stage IV, Step 4 (waste volume and concentration) and the total volume of impounded wastes (determined as above). The exact method of deriving pollutant loading will depend on the model requirements and on whether the impoundment is lined. In the cases where monitoring data exist for the impoundment(s) of interest, this data can be used in place of estimated concentration.

Step 3. Estimate releases to air, surface waters, and groundwater from each surface impoundment handling the subject waste, using an appropriate model. The exact output of this effort will depend on the model(s) selected.

Step 4. If monitoring data are available, compare with predicted concentrations. If estimated concentrations do not corroborate measured values, use best judgment to evaluate the discrepancy. If applicable, calibrate the model and rerun. See Volumes 1, 2, and 5 of this series for guidance on completing the exposure assessment.

Very few monitoring data are available for surface impoundments. Monitoring data for some sites are included in the auxiliary information in the SIA data base; a retrieval from that data base would include such data when they exist. However, these data are highly variable with regard to both quality and quantity. Monitoring of surface impoundments is required under RCRA. Unfortunately, there are no plans to computerize this data, which is available only through individual states or EPA regional offices.

6. PUBLICLY OWNED TREATMENT WORKS (POTWs)

Public sewage authorities collect and treat residential, commercial, and industrial wastewaters, as well as groundwater seepage and storm waters. Their capabilities range from collection without treatment to collection with advanced wastewater treatment. Exposure to chemical substances from POTWs can occur via the discharge of treated or untreated municipal wastewaters to surface waters or to groundwater, by volatilization of chemicals during treatment, and through treatment and disposal of sludges. Background information on POTWs is given in Section 6.1. Section 6.2 comprises the Stage IV decision tree, and Section 6.3 discusses Stage V. Information on computer retrievals of POTW data is included in Section 6.1. In general, there is considerable information available on the location and design of POTWs, less information on chemical inputs to POTWs, and limited tools for predicting releases of specific chemicals from POTWs. Some monitoring data are available.

6.1 Background Information

Information on municipal wastewater treatment by POTWs, occurrence of chemicals in sludges and wastewaters, and tools for estimating environmental releases are discussed below. This section provides the information base for the Stage IV and Stage V decision trees.

6.1.1 General

A variety of treatment types are currently in use at municipal treatment plants (POTWs) nationwide. Regardless of the treatment type, however, POTWs usually operate 24 hours per day. Wastewater treatment plants can be categorized into the following general classes, depending on the degree of treatment: preliminary, primary, secondary, and tertiary. Effluents discharged from plants that have preliminary treatment are considered "raw" wastewater. Preliminary treatment includes comminution, screening, and grit removal. Primary treatment goes beyond this to remove most settleable solids. For regulatory purposes, it is defined as producing effluent that does not meet secondary treatment standards; conventional primary treatment generally provides preliminary treatment plus primary sedimentation. Advanced primary treatment includes some biological treatment as well (Culp 1979).

Secondary treatment consists of preliminary plus biological processes with no additional process except disinfection. Biological processes include treatment by trickling filters, activated sludge, and rotating biological contactors. Advanced secondary treatment consistently provides effluents with low biochemical oxygen demand (BOD) (24-10 mg/l) and the removal of nutrients, phosphorous, and/or ammonia. Tertiary treatment is defined in terms of the effluent BOD and the removal of nitrogen; tertiary plants must consistently produce effluent with a BOD less than 10 mg/l and have specific processes that can remove more than 50 percent of the total nitrogen present in the influent wastewaters (Culp 1979).

Finally, the "no discharge" category includes lagoon systems designed for evaporation and/or infiltration. To a lesser degree, wastewaters in this category are treated by recycling, reuse, spray irrigation, or groundwater recharge. Surface impoundments are associated with many wastewater treatment processes and may be used for storage, treatment, or disposal (USEPA 1981e).

By mandate of the Federal Water Pollution Control Act (FWPCA), there is a large body of readily available data on municipal wastewater collection and treatment that will aid in the assessment of exposure to toxic pollutants from this source. In particular, the annual Needs Survey conducted by the Priority Needs Branch of the EPA Office of Water Program Operations provides a wealth of both site-specific and generic data in the form of computer retrievals and publications. The national summary of municipal wastewater treatment presented in Table 7 in Section 2.3.3(3) is derived from the 1980 Needs Survey (USEPA 1981e). A total of about 97,117,000 m3/day of wastewater was treated by POTWs in 1980.

Of the 30 percent of the U.S. population not served by public sewage authorities, the majority is probably served by on-site septic tanks or leachfields; however, the Needs Survey does not give this information. This report does not consider disposal of wastewaters on-site.

Nationwide, about 83 percent of wastewaters treated by POTWs are of domestic (residential or commercial) origin, the balance being contributed by industrial plants (USEPA 1981e). The extent of industrial wastewater treatment by POTWs varies widely from locality to locality, ranging from treatment plants that receive no industrial effluents to plants that are operated jointly by a sewage authority and an industry, treating a large volume of industrial wastewaters. The degree to which industrial wastewaters are discharged indirectly (i.e., via POTWs to surface waters) depends on many factors, including the treatment capability of the local POTW, the nature of the industrial wastewaters, cost considerations on the part of both the industry and the sewage authority, and federal and state policies and regulations. The EPA is developing pretreatment standards applicable to a number of industries that discharge to POTWs.

6.1.2 Chemical Substances in POTW Effluent and Sludge

Metallic and nonvolatile organic compounds in the influent wastewater to POTWs can accumulate in the sludge. The extent of this accumulation depends on the chemical properties of the substance, its concentration in the influent stream, and the design and operating characteristics of the plant. A portion of the more volatile organic chemicals is lost to the atmosphere during treatment processes. The balance of the chemical is generally discharged with the plant effluent to surface waters (and sometimes groundwater). Some toxic substances, most notably several chlorinated hydrocarbons, are formed during the treatment process (Burns and Roe 1982); other substances may undergo biotransformation (USEPA 1979c). The Effluent Guidelines Division (EGD) of EPA has undertaken a study of priority pollutants in POTW influent, effluent, and sludge, based on sampling of 50 different plants (Burns and Roe 1982). The results provide information on removal efficiencies of the priority pollutants detected. Tables H-1 through H-7 in Appendix H give the summary statistics from the study, including concentrations of priority pollutants in influent, secondary effluent, and raw sludge, as well as percent removal by various treatment methods. In the absence of more reliable data, these results can be used as surrogate data to estimate removal efficiencies of other compounds with similar chemical properties.

6.1.3 Predicting Releases of Chemical Substances from POTWs

Some attempts have been made to model POTW processes, but this study has not identified any validated models that can accurately predict releases to air, water, and sludge based on influent concentration for the range of available wastewater and sludge treatment processes. The Monitoring and Data Support Division (MDSD) of the EPA Office of Water Regulations and Standards has developed a POTW model that might be adaptable to the needs of some exposure assessments. This model predicts the releases of priority pollutants to surface waters and to sludge based on the following variables: (1) known or estimated influent concentrations and flow; (2) estimated removal efficiency; and (3) estimated loss through volatilization. The removal efficiencies are based on the POTW study of Burns and Roe 1982. This model is already connected with the Industrial Facilities Discharge (IFD) file (see Section 2.3.3(3) and Exhibit H-2 in Appendix H), which facilitates modeling of the aquatic transport and fate. The model is very limited, however, in that: (1) it does not model releases to air; (2) it predicts aqueous effluent releases for only priority pollutants; and (3) it models only one treatment configuration (typical secondary treatment). Ideally, a POTW model for exposure assessments would predict toxic substance concentrations and total waste volume for releases to air, effluent water, and sludge, based on treatment (including sludge treatment). It would take into account the inhibitory effects that high concentrations of certain toxic chemicals have on treatment efficiency and would consider the wastewater of interest in the context of the total influent flow to the POTW.

In the absence of a model, there are some available data that may be used to predict environmental releases. The Needs Survey (described in detail in Exhibit H-1 in Appendix H) contains site-specific information on flows, treatment type, and populations served, and can be accessed by computer. The Needs Survey report (USEPA 1981e) provides the per capita domestic wastewater generation rate which is 479 liters/capita/day nationwide. (Domestic wastewater includes both residential and commercial wastewaters.) The Needs Survey provides both site-specific information and generic data. Together with the sludge generation factors given in Table 34, these data can be used to estimate effluent flow, as well as volume of sludge generated at a particular plant. The removal efficiencies and concentrations of some chemical substances in the sludge and POTW effluent may be very roughly estimated using the data in Tables H-1 through H-7 in Appendix H for priority pollutants and possibly for chemicals that are structurally similar to the priority pollutants studied. The typical moisture and solids content of a sludge after various treatments can be estimated from data in Table 35. Finally, as a result of the National Pollution Discharge Elimination System (NPDES), some site-specific information on flow and concentrations of toxic chemicals in effluent is available for all major industries that discharge to POTWs. The flow and Standard Industrial Classification (SIC) codes of plants belonging to one of the 21 major industries (see Table D-8 in Appendix 8) that discharge indirectly are available from the Industrial Facilities Discharge (IFD) file (see Appendix H), along with the NPDES permit number of the POTW to which they discharge. Thus, for any given POTW, the identity of the major industrial contributors is readily available; conversely, for a known plant, the POTW to which it discharges (if any) is easily learned.

The EPA Office of Toxic Substances (OTS) is sponsoring a project to tabulate frequency distributions of (1) POTW plant flows, (2) receiving stream flows, and (3) dilution factors for all POTWs in the IFD data base. These frequency distributions will be invaluable tools in nationwide exposure assessments involving releases of chemicals from POTWs.

Monitoring data on POTW effluents and sludges are not available for many plants, and any available data will usually be limited to priority priority pollutants. The POTW study conducted by EGD (Burns and Roe 1982) contains site-specific monitoring data for 50 "typical" POTWs in the U.S. It also provides data on the reduction of priority pollutants

Table 34. Sludge Generation Factors in Wastewater Treatment, kg/m^{3}[a]

Type of wastewater treatment	Raw sludge generated	Sludge quantity after anaerobic digestion	Sludge quantity after dewatering and incineration	Sludge quantity after dewatering and composting
Primary	0.13 (0.55)	0.074 (0.31)	0.056 (0.235)	0.15 (0.63)
Secondary	0.18 (0.76)	0.11 (0.48)	0.073 (0.305)	0.21 (0.87)
Advanced[b]	0.25 (1.05)	0.195 (0.815)	0.10 (0.43)	0.27[c] (1.21[c])

[a] Tons/Mgal in parentheses.

[b] Phosphorous removal using ferric chloride.

[c] For 20% solids sludge which has been bulked with wood chips and has undergone screening to remove coarse particles after composting. If all wood chips were removed, the quantities of composted sludge remaining would be equivalent to those remaining after anaerobic digestion.

Source: Walker 1979.

Table 35. Solids Content in Sludges in Relation to Treatment

Sludge treatment	Solids content %	Comments
Raw primary sludge after thickening	1-3	Conditioning, which occurs prior to thickening or dewatering, does not change solids content appreciably.
Raw secondary activated sludge	0.5-1	
after thickening	3-6	
Sludge stabilization (aerobic or anaerobic digestion)	See comment	Converts 50% of organic solids to liquid and gas forms.
Dewatering in sandbeds	45	Occurs after digestion. After 6 weeks of drying solids, content may be as high as 85-90%. In the past, was the most popular method of dewatering.
Vacuum filter	15-30	After this process, sludges can be placed in landfills, landspread, or incinerated. Currently, the most popular method of dewatering.
Pressure filtration	40-50	Not widely used in U.S.

Source: Culp 1979.

effected by individual treatment processes. The Permit Compliance System (PCS), a computerized data base maintained by the EPA Office of Water Enforcement and Permits, contains effluent sampling data for the major NPDES permit holders, including major municipal treatment plants. However, data are generally limited to conventional and selected priority pollutants. Limited additional data may be in the NPDES files at EPA regional offices or in the corresponding state agency files. Some of the states that have their own NPDES programs may have computerized data bases containing effluent information for permits.

6.2 Allocating Wastewater to Individual POTWs - Stage IV Decision Tree

The output of the Stage IV decision tree depends on the scope and depth of the assessment. At the greatest level of detail, it will provide a list of all POTWs that are probable candidates for disposal of the subject wastewater, together with their individual capacities and current operating characteristics. For more general assessments, it will provide for each POTW treatment configuration of interest estimates of (1) the typical quantity of the subject waste stream treated per plant and (2) the number of plants (if needed in the exposure assessment). The latter information may be provided on a nationwide basis or may be limited to the POTWs of a specific region or those receiving the wastewaters of a specific industry segment (identified by SIC code).

There is a considerable body of fairly reliable data for this decision tree. Note that in the case of detailed assessments requiring computer retrievals, Stage IV will usually be performed along with the Stage III decision tree for wastewater as a single integrated operation.

In order to evaluate the potential for environmental releases from treatment, storage, and disposal of wastewaters in surface impoundments, deepwell injection, or land treatment of wastewater, the user will have to consult the information in Sections 4 and 5, as well as this section. Keep in mind that the information on how a POTW treats its wastewaters and sludges and on the characteristics and quantities of waste generated will come from this section. In order to find out what happens to toxic chemicals in wastewaters that are landspread, placed in surface impoundments, or deep-well injected, see Sections 4, 5, and 8, respectively.

Step 1. List the POTWs that are probable candidates for disposal of the subject wastewater together with their capacities and current operating characteristics. (See 1.a for domestic wastewaters and 1.b for industrial wastewaters.)

a. Domestic wastewaters. If the assessment is nationwide in scope, then all of the POTWs in the U.S. are to be considered. Instead of compiling a list, consult Table 7 for a breakdown of the nation's POTWs by treatment types. Alternatively, use the data compiled by OTS on the frequency distribution of POTW flows in the U.S. (see description in Section 6.1).

For assessments of regional or statewide scope, consult the annual summary of Needs Survey data base (USEPA 1981e). This provides POTW flow rates and treatment type breakdowns for each state. Summaries from the Needs Survey of the treatment populations and domestic flows by state are provided in Tables D-1 and D-2 in Appendix D.

For assessments requiring site-specific data, a computer retrieval from the Needs Survey data base is recommended (Exhibit H-1 in Appendix H). This can provide not only the proportion of the subject wastewater treated by POTWs (the usual output of Stage III for wastewater), but also (1) a list of the individual POTWs in a specified county, sewer district, or other local area; (2) the capacity and current flow of each listed POTW; and (3) the type and level of wastewater treatment employed at each listed POTW. Thus, a single retrieval should suffice for both stages. At the same time, data may be retrieved on treatment methods employed for sludges (see Step 2).

b. Industrial wastewaters. If the assessment is nationwide in scope and the industry is widespread, then almost all of the POTWs in the U.S. are to be considered. Therefore, instead of compiling a list, consult Table 7 for a breakdown of the nation's POTWs by treatment types.

If greater geographic resolution is required, a computer retrieval from the IFD data base is recommended (see Exhibit H-2 in Appendix H). In this case, Stages III (for wastewater) and IV (for POTWs) are usually performed together as one operation. For industry-wide assessments, the data base may be accessed by SIC code; a geographic limitation can be superimposed on this if desired. The retrieval will identify each receiving POTW with data on flow. For information on all POTWs receiving industrial wastewaters in a given area, the user can specify the area and the SIC code 4952, which pertains to POTWs. This will identify each industrial plant which discharges to each POTW, and will provide flow data. A Needs Survey data base retrieval can then be conducted for information on treatment types employed.

For new "hypothetical" plants that are likely to discharge to POTWs (based on the available EGD documents on industrial wastewater practices or other information), the candidate POTWs can be chosen by examining both the IFD and the Needs Survey retrievals. The Needs Survey retrieval will list all of the POTWs in the area. The IFD will show which area POTWs are already receiving industrial wastes; in the absence of better information, assume that these plants will be able to handle the new plant's effluent as well.

When conducting Needs Survey retrievals, do not forget to include a request for information on sludge treatment methods employed (see Step 2).

Step 2. Determine the methods of sludge treatment employed by subject POTWs. Acquisition of sludge treatment information actually constitutes part of the Stage III decision tree for POTW sludges (Section 2.2.3(2)). It is included here as a reminder to request sludge treatment information when conducting a Needs Survey retrieval as directed in Step 1 above.

6.3 Estimating Releases from POTWs - Stage V Decision Tree

In this stage, the user estimates releases to surface waters from POTW effluents based on knowledge of influent concentrations and plant design/operating conditions. The output of this stage is a compilation of releases (mass per unit time), chemical concentrations (mass per mass or mass per volume), and flow (volume per unit time) associated with aqueous discharges from POTWs. Releases to air from POTWs may also be estimated in Stage V, provided that reliable monitoring data or estimation methods are available. In order to estimate releases from land treatment, surface impoundment, or deep-well injection of POTW wastewaters, the user is referred to the Stage V decision trees for those disposal methods.

A detailed decision tree has not been developed for this stage, since the lack of a generally useful model precludes the accurate estimation of releases. The Stage V output should also include estimates of the quantity of POTW sludge and of the quantity of the subject chemical in the sludge. (This information is input for the estimation of environmental releases associated with disposal of the sludge, starting with Stage III.)

Step 1. Identify and list the significant POTW design and operating characteristics that affect environmental releases of chemical substances.

The type of wastewater and sludge treatment components, and the plant design capacity in relationship to actual quantity of wastewaters treated are the key factors that determine environmental releases of chemicals from POTWs.

Step 2. Determine which of the parameters listed in Step 1 are known for the site(s) of interest based on accessible (e.g., computerized) data.

Information on wastewater and sludge treatment components and on current design and operating capacity is available in computerized form from a Needs Survey retrieval where site-specific data is required. For regional or large-scale exposure assessments where exposure estimates for a large geographical area (e.g. nationwide) will be based on extrapolation from one or more "typical" plants, design and operating capacity from such typical plants can be extracted from the annual Needs Survey summary (e.g., USEPA 1981e) or from a Needs Survey retrieval for the region of interest. See Table H-8 in Appendix H for a listing of the treatment components included in the Needs Survey and Exhibit H-1 in Appendix H for a description of the scope and utility of the Needs Survey. Note that the information required for this step should be coordinated with other information needed from the Needs Survey so that only one retrieval is necessary (see Sections 2.3.3(2), 2.3.3(3) and 6.2).

Step 3. Identify a suitable approach for predicting environmental releases based on design/operating characteristics.

The only model identified in this study as potentially useful in estimating chemical releases from POTWs is the POTW model developed by the Monitoring and Data Support Division (MSDS) of the EPA Office of Water Regulations and Standards (see Section 6.1.3 for a discussion of the scope and limitations of this model). The MDSD POTW model may be useful in exposure assessments of priority pollutants (or of analogous chemicals) in cases where the model POTW (based on a typical plant with secondary treatment) adequately represents the POTWs of interest in the assessment. In the case of exposure assessments for which the MDSD model is not suitable, data allowing estimation of the partitioning of the chemical or a suitable analog among aqueous effluent, sludge, and air should be procured. The only such source of data identified in this study is the Burns and Roe (1982) report which is limited to priority pollutant (see Tables H-1 through H-7 in Appendix H).

Step 4. Using the available predictive approach, estimate the releases to water and to sludge of the chemical from each POTW of interest in the assessment. (Chemical releases to air from POTWs are not usually evaluated in exposure assessments, because they are assumed to result in insignificant exposure.)

Step 5. Compare estimates from Step 4 with available monitoring data, if any. If estimates and monitoring data do not agree, re-evaluate the predictive methods and repeat the analysis, if necessary.

Step 6. Use the estimates of sludge generated as input to Stage III (Section 2.3.3(2)) and complete the analysis of environmental releases from disposal of the sludge.

Step 7. Complete the exposure assessment using Volumes 1, 2, and 5 of this methods development series. POTW effluents are usually treated as a point source in the analysis of environmental fate.

7. INCINERATION

Incineration is the controlled burning of wastes resulting in their thermal destruction. Toxic gases and particulates may be emitted to the air during incineration, and incinerator residues require ultimate disposal to land and surface water. Considerable information is available on the location and design of incinerators. However, this study identified no validated model for estimating environmental releases of a range of chemicals from incinerators or for predicting the chemical composition of incinerator residues. Thus, there will be considerable uncertainty in the Stage V estimates until an appropriate predictive approach is developed. Background information on this method is presented in Section 7.1, followed by the Stage IV and Stage V decision trees in Sections 7.2 and 7.3. For information on the ultimate disposal of and environmental releases from incineration residues, see Section 2.3.3(1).

7.1 Background Information

This section presents information that is the basis for the Stage IV and Stage V decision trees on incineration. This includes discussions of the types and numbers of incinerators, important information resources on incineration, emissions and by-products of incineration, and approaches to estimating environmental releases.

7.1.1 General

Incineration is currently used as a waste treatment method for municipal sludge, municipal solid waste (MSW), and industrial wastes (hazardous and nonhazardous). Some incinerators are designed for some form of resource recovery, most often steam production. The advantages of incineration as a waste treatment technique are that the waste volume is considerably reduced and the resulting residues are largely inert. Disadvantages include the expensive air pollution control equipment and high energy requirements necessary for compliance with regulations issued under the Clean Air Act and the Resource Conservation and Recovery Act (RCRA).

Four classes of incinerators have been defined for regulatory purposes: municipal, sewage sludge, industrial, and hazardous waste incinerators. (Hazardous waste incinerators are actually a subset of industrial incinerators.) Industrial boilers sometimes burn refuse-derived fuel (RDF), which may contain toxic chemicals. However, they are not currently subject to federal regulation, and little is known about their operating characteristics or the types of waste they burn. Industrial boilers will not be considered further in this report; however, an inventory of municipal waste-fired boilers is presented in

Appendix I, Table I-1. Certain other methods of thermal waste treatment are not yet widely used in the U.S. and will not be discussed in this report. These include wet air oxidation, flash drying, and pyrolysis. Each major category of incinerators is discussed below.

(1) Municipal incinerators. Municipal incinerators are defined as incinerators that burn at least 50 percent municipal solid waste. Their numbers have decreased in the last decade because of the high cost of air pollution control equipment and energy. The total national solid waste disposal capacity of incinerators decreased by 40 percent between 1971 and 1976 (Helfand 1979a). In 1972, there were 193 incinerator plants, and in 1977 there were only 103 incinerator plants with 252 furnaces and a total solid waste disposal capacity of about 36,000 kkg/day. More recent surveys of municipal incinerators are presented as Tables I-2 and I-3 in Appendix I of this report. These indicate that there are currently only 90 small municipal incinerators (capacity less than 45 kkg/day) and 46 large municipal incinerators (capacities between 48 and 1,450 kkg/day). (Although the data do not specify whether it is plants or furnaces that are enumerated, it is most likely that the figures refer to plants.)

Four types of furnaces are used for incineration of MSW: vertical circular, multicell rectangular, rectangular, and rotary kiln furnaces. The rectangular furnace is the most common type (Helfand 1979a). When these furnaces are properly operated, the following temperatures are typical of various stages in the incineration process:

- Temperature of gases immediately above burning wastes: 1150°-1370°C
- Temperature of gases when they leave combustion chamber: 760°-980°C
- Temperature of gas entering stack: less than 540°C

Municipal incinerators are routinely operated for periods of from 8 to 24 hours a day for 5 to 7 days a week. One survey showed that 53 percent operated 24 hours a day and 36 percent operated 8 hours a day. The current trend is toward 24-hour operation (Rubel 1974).

Several kinds of emission control devices used are on municipal incinerators. Incinerators constructed between 1955 and 1965 generally used mechanical cyclone collectors, which have particulate removal efficiencies of 60 to 80 percent. Other emission control systems installed included various scrubber techniques and electrostatic precipitators (ESP).

(2) Sewage sludge incinerators. Disposal of municipal wastewater treatment sludge by incineration is the most common method of handling these sludges (see Table 6 in Section 2.3.3(2)). Sewage sludge

incinerators are defined as those that burn more than 50 percent sewage sludge (Helfand 1979b). In 1979, it was estimated that 240 municipal sewage sludge incinerators were in operation. The majority (80 percent) of the plants have multiple hearth furnaces (MHF) which burn an estimated 85 to 90 percent of the incineration sludge (Helfand 1979b, USEPA 1979a). Most of the remaining sewage sludge incinerators are fluidized bed reactors (a relatively new technology). Electric (infrared) incinerators are even newer and are used by about nine plants (Helfand 1979b). Thirty- eight states have at least one sludge incineration facility. Figure I-1 in Appendix I presents the geographic distribution of sewage sludge incinerators in 1978. Sewage sludge incinerators generally use sludge that has at least 20 percent solids. Multiple hearth incinerators have capacity ranging from 91 to 3600 kg/hr of dry sludge with operating temperatures ranging from 700°C to 1100°C. Gas temperatures may exceed 760°C in the combustion zone.

Scrubber equipment has been the traditional air pollution control in sewage sludge incinerators. Control technology in place today includes Venturi scrubbers in series with cyclonic mist eliminators, impingement type scrubbers, or multiple series of perforated plate impingement scrubbers. No plants employed baghouse or electrostatic precipitators in 1978, but these are expected to be used in the future (Helfand 1979b).

(3) Industrial incinerators. This category of incinerators has been defined by the EPA as any combustion unit used in the process of burning a nongaseous industrial waste stream (including hazardous waste) which does not recover any heat for a useful purpose (USEPA 1980d). By this definition, an industrial waste stream means any waste stream that is composed of more than 50 percent by weight of waste generated at a manufacturing establishment or collected by a resource recovery establishment. Industrial incinerator designs in use include single chamber, multiple chamber, rotary kiln, rotary hearth, multiple hearth, liquid injection, conical, and fluidized bed units. Commercial off-site incineration facilities generally use the rotary type and operate 24 hours per day.

The total estimated population of incinerators used by manufacturing industries is given in Table I-4 in Appendix I. Table I-5 presents an up-to-date inventory of all hazardous waste incinerators, a subset of industrial incinerators. (Because hazardous waste incinerators are a subset of the industrial incinerator population, the incinerators listed in Table I-5 are probably also included in Table I-4.) Table 36 presents a list of commercial (off-site) hazardous waste incinerators.

7.1.2 Information Resources

Information on the number of incinerators in each category comes from a variety of sources. Incinerators that are considered major sources (emitting 100 tons/year of a criteria pollutant) are listed in

Table 36. Commercial Off-site Hazardous Waste Disposal Facilities Offering Incineration Services in 1980

EPA Region	Number of facilites	Amount of waste handled, thousands of wet kkg	Percentage of off-site wastes handled[a]	Percentage of total wastes handled[b]
I	3	23	7.7	2.1
II	1	26	4.0	0.83
III	1	48	7.9	1.1
IV	7	65	7.1	0.62
V	6	97	7.3	1.5
VI	6	98	9.5	0.93
VII	0	0	0	0
VIII	0	0	0	0
IX	1	40	7.5	1.4
X	0	0	0	0
TOTAL	25	398	6.6	0.97

[a] Percentage of all off-site handled wastes incinerated.

[b] Percentage of all hazardous wastes generated that are handled by off-site incinerators.

Source: USEPA 1980b.

the National Emissions Data System (NEDS) data base (see Appendices A and C of Volume 2 of this report). Hazardous waste incinerators are entered into the Hazardous Waste Data Management System (HWDMS) data base (see Section 2.3.3(4) and Exhibit D-1 in Appendix D). Tables I-2 through I-5 in Appendix I present inventories prepared by EPA. Commercial incinerators other than those handling hazardous wastes have not been well studied and are not considered here.

Information on environmental releases from incinerators is available from sources mentioned in Section 7.1.3, and from air data bases listed in Volume 2, Appendix A of this methods development series.

7.1.3 Emissions and Products of Incineration

Incineration produces a number of by-products, including gases and particulates (fly ash) emitted to the air, scrubber water and other wastewater, and bottom ash. The disposal methods and characteristics associated with the ash and wastewater are discussed in Section 2.3.3(1). The air releases depend on the kind of waste, the design of the incinerator, and the pollution control equipment. The particulate matter that is not trapped by the pollution control device becomes an air release. The following is a summary of typical fly ash collection efficiencies of different control devices (Rubel 1974):

- Settling: 0 to 31 percent
- Multicyclone: 30 to 80 percent
- Tangential inlet cyclones: 30 to 70 percent
- Scrubber: 80 to 95 percent
- Electrostatic precipitator: 90 to 97 percent
- Fabric filter: 97 to 99 percent

Typical air emission factors from sewage sludge incineration are given in Table 37. Tables I-6 and I-7 in Appendix I present typical emission factors from municipal and industrial incinerators. Tables 38 and 39 give a summary of the data collected during this study on environmental releases from municipal incinerators. Because of the limited nature of these data, they are not necessarily typical of municipal incinerators in general. Chemical reactions inside incinerators are quite complex; some organic chemical species are transformed to other species in the process. In addition, the toxic constituents in municipal solid waste vary regionally. Emission factors cannot be estimated reliably unless the toxic concentrations in the waste feed are measured.

The amount of ash produced by incineration depends on the type of waste and the type of incinerator. Incineration of sewage sludge typically produces a residue that is about 40 percent by dry weight of

Table 37. Emission Factors from Sludge Incineration

Incinerator type	Sludge characteristics[a] % moisture	Sludge characteristics[a] % solids (% ash/% volatiles)	Uncontrolled emissions, kg/Mg[a] typical	Uncontrolled emissions, kg/Mg[a] reported range	Controlled emissions kg/Mg
Multiple hearth	67-80	15-33 (20-45/55-80)	41-75	17-110	0.20-1.5[b]
Fluidized bed	75	25 (15/85)	23-47	9-171	0.10[c]
Electric (infrared)	85	15 (50/50)	9	--	0.46-0.65[d]

[a] Number of incinerators sampled was not given.

[b] Based on samples from 21 incinerators equipped with Venturi/impingement scrubber.

[c] Based on one incinerator with a Venturi scrubber.

[d] Based on samples from 3 incinerators, 2 of which were equipped with Venturi/impingement scrubber.

Source: **Helfand 1979b.**

Table 38. Summary of Total Organic Chlorine (TOCl) Inputs and Emissions at the Chicago Northwest Incinerator[a]

	Mean	Standard deviation
Refuse input		
Feed rate, kg/hr	17,200	1,440
TOCl conc. ng/g	590	1,180
TOCl input, mg/hr	9,800	18,700
Emissions		
Combined ash [b]		
Mass flow, kg/hr	4,500	800
TOCl conc., ng/g	8.1	7.6
TOCl emissions, mg/hr	35	34
Flue gas[c]		
Mass emissions, dscm/hr	86,780	6,830
TOCl conc., ng/dscm	3,200	3,500
TOCl emissions, mg/hr	285	327
Percent of TOCl emissions		
Combined ash	13	12
Flue gas	87	12
Overall Destruction Rate of TOCl, %[d]	97	

[a] Thirteen samples taken over a 13-day period. The Chicago Northwest Incinerator is a continuously operating municipal incinerator with a furnace temperature of 1,160°F. The total weight reduction through incineration ranges from 52 to 65%.

[b] Includes bottom ash and electrostatic precipitator (ESP) ash.

[c] Flue gas collected at the ESP outlet.

[d] This study assessed measurement errors of TOCl by adding known amounts of two surrogate compounds, d_8-naphthalene and d_{12}-chrysene, to specimens before chemical analysis. Total percent recoveries for the surrogates were low. Recoveries for d_8-naphthalene were in the range of 10-50%, and recoveries for d_{12}-chrysene were typically 30-60%. If the percent recoveries are indicative of the recovery rate for TOCl, then TOCl concentrations are underestimated.

Source: MRI 1981.

Table 39. Organic Compounds Quantitated in the Emission Media for the Chicago Northwest Incinerator[a]

	Flue gas outlet emission rate, mg/hr	Combined ash emission rate, mg/hr
Phenanthrene	9.2 - 28	-
Fluoranthene	2.2 - 4.4	ND - 78
Pyrene	6.6 - 8.0	ND - 56
1,3-Dichlorobenzene	ND	ND
1,4-Dichlorobenzene	ND	ND
1,2-Dichlorobenzene	ND	ND
1,2,3-Trichlorobenzene	4.0 - 12	ND
1,2,4-Trichlorobenzene	17 - 48	ND
1,3,5-Trichlorobenzene	15 - 40	ND
Tetrachlorobenzene	54 - 120	ND
Hexachlorobenzene	4.0 - 22	ND
Dichlorophenol	22 - 54	ND
Trichlorophenol	98 - 160	ND
Tetrachlorophenol	96 - 140	ND
Pentachlorophenol	14 - 36	ND
Dibenzofuran	5.8 - 11	ND
PCBs	1.1 - 7.8	
Dimethylphthalate		ND - 400
Diethylphthalate		ND
Di-n-butylphthalate		54 - 260
Butylbenzylphthalate		ND
Bis (2-ethylhexyl)-phthalate		420 - 3,000

[a] See Table 38 for information on this study. ND denotes that the compound was not detected. Blank denotes sampling not performed. Composite refuse extracts were not analyzed so no destruction efficiency can be determined.

Source: MRI 1981.

the original dry weight of the sludge (Walker 1979). The typical ash content of MSW is given in Table 13 in Section 2.3.3(6). The ash in the study reported in Table 38 was 26 percent of the waste feed by weight.

7.1.4 Estimating Emissions from Incineration

No validated models that predict emissions of a variety of chemical substances from incinerators based on waste constituents and on facility design and operating factors were identified in this study. The quantity and composition of the by-products depend on a number of factors, including type of waste, moisture content of waste, residence time of waste, operating temperature, degree of mixing, excess air, waste feed rate, mode of waste input, and type of pollution control equipment. The EPA Office of Solid Waste is currently undertaking studies that may culminate in some standard emission factors that can be used to estimate toxic emissions. Work is also underway to characterize the operating conditions of existing hazardous waste incinerators and to develop models for predicting mass balances for incinerated chemical substances; this work is being sponsored by the EPA Office of Research and Development (ORD) in Cincinnati. Meanwhile, a model that has recently been developed by ORD for determining the destruction efficiency of hazardous wastes in boilers (Wolbach 1982) is potentially adaptable to incinerators as well. Numerous sampling studies of incinerator emissions are also in progress. Until there is a suitable model, however, estimates of emissions will have to be based on evaluation of available monitoring and test burn data.

A large amount of trial burn data will probably be generated as a result of recently promulgated regulations regarding the issuance of hazardous waste incineration permits under RCRA (USEPA 1981c, 1982b). Permit applicants must specify the waste feed mixtures they intend to burn. The permit then specifies for each mixture a principal organic hazardous constituent (POHC) which must be destroyed or removed as required by the applicable performance standard. The applicants must conduct trial burns and submit to EPA the calculated destruction and removal efficiency (DRE) for these POHCs. They must also supply sufficient information to determine whether the POHCs are primarily destroyed through combustion or are removed either by air pollution control equipment or by partitioning into the bottom ash. (The applicant is not required to provide a detailed mass balance, however.) Detailed data are also required on the average, maximum, and minimum temperatures in the combustion zone and the air feed rate. Unfortunately, while these data will be available through the various EPA regional offices, they will not be easily retrievable; plans to enter these data into a computerized data base have been indefinitely postponed. Meanwhile, a report summarizing most of these data is being prepared under the sponsorship of EPA-ORD in Cincinnati.

Currently feasible approaches for estimating environmental releases from incinerators are presented in the Stage V decision tree (Section 7.3). Once emission factors are known (or estimated), the dispersion of releases to the ambient air may be modeled using the procedure for point sources outlined in Volume 2 of this report. EPA has recently published a document that provides guidelines on how to model the environmental fate of environmental releases from hazardous waste incinerators and includes information on suggested screening mechanisms (USEPA 1981a); this report should be consulted by users of this methods development series.

7.2 Allocating Waste Streams to Individual Incinerators - Stage IV Decision Tree

The procedure for estimating the amount of a waste that is handled at each receiving incinerator is presented in this section. First, the user determines what subpopulation of incinerators might handle the waste. Knowledge of the waste characteristics and whether disposal will be on- or off-site is helpful here. Then the user estimates the amount of the waste treated at each of the candidate facilities. The information base for this decision tree is fairly comprehensive for all but nonhazardous industrial waste incinerators.

The input to this stage is the Stage III estimate of waste quantity and chemical concentration produced per unit time, and information on the source of the waste. The output of Stage IV is a list of candidate incinerator sites and estimates of the quantity of the subject waste treated at each site.

Step 1. **Determine whether the disposal of the subject waste will be limited to certain types of incinerators. The output of this step will be a list of the types of incinerators that are candidates for disposal of waste.**

a. Municipal solid waste. MSW is generally burned in rectangular furnaces. Other types include vertical circular, multicell rectangular, rectangular, and rotary kiln.

b. Municipal sludge. Sewage sludge will generally be incinerated in a multiple hearth incinerator, although sometimes fluidized bed or electric incinerators are used (see Section 7.1.1).

c. Hazardous wastes. Check Table I-8 in Appendix I to see whether disposal will be limited to certain types of hazardous waste incinerators. Knowledge of the physical and chemical nature of the waste is essential here.

d. Nonhazardous industrial solid waste. Industrial waste may be burned in single-chamber, multiple-chamber, rotary kiln, rotary hearth, multiple hearth, liquid injection, conical, and fluidized/ bed incinerators. See Table I-8 in Appendix I to narrow the possibilities further.

Step 2. **If applicable, determine the percentage of the waste that will be disposed of on-site versus off-site. This knowledge will be useful in identifying the population of incinerators that is likely to receive it (Step 3).**

a. Municipal solid waste. By definition, disposal of MSW occurs off-site; therefore 100 percent of the subject waste will be disposed of off-site.

b. Municipal sludge. Sludge incinerators are usually located at or near the POTW; an exception is the case where one POTW sends sludges to another for treatment. Assume that 100 percent of the subject waste is disposed of on-site.

c. Hazardous wastes. Most hazardous wastes that are incineration rated are treated on-site. (There are approximately 400 hazardous waste incinerators in the U.S., only 25 of which are commercial off-site facilities, see Section 7.1.1.) For industry-specific incineration practices, consult information on incineration in Appendix C and Table D-5 in Appendix D.

d. Nonhazardous industrial solid waste. The available information suggests that there are few, if any, nonhazardous off-site commercial incineration facilities. Therefore, assume that 100 percent of the subject waste will be incinerated on-site. This assumption could be confirmed by comparing an HWDMS retrieval with a National Emissions Data System (NEDS) data base retrieval to see whether all incinerators not in the HWDMS data base are on-site. Information on the NEDS data base is included in Appendix A of Volume 2 of this methods development series.

Step 3. **Identify the incinerators that are probable candidates for treatment of the waste based on information in Steps 1 and 2 above and available inventories (computerized or otherwise) of disposal facilities. The output of this step will be a list of all of the candidate incinerator sites in the study area.**

a. Municipal solid waste. See the current inventories of municipal incinerators in Tables I-2 and I-3 in Appendix I. These inventories give the location of each incinerator (by city and state). Incinerators located in the study area are candidates for treatment of the subject waste.

b. Municipal sludge. Based on the Needs survey data base retrieval, all of the POTWs that treat sludges by incineration in the study area will be known (see Sections 2.3.3(2) and 6, and Exhibit H-1 in Appendix H). The Needs survey retrieval will also indicate the type of incinerator on-site. These will be the candidate facilities for treatment of the subject waste.

c. Hazardous waste. The facilities in the study area that incinerate hazardous wastes will be known from the Hazardous Waste Data Management System (HWDMS) retrieval (see Section 2.3.3(4) and Exhibit D-1 in Appendix D). (Be sure to check with OSW to cull the incorrect entries from the HWDMS retrieval before using this information.) If the generator(s) of the subject waste have on-site incinerators, these incinerators are candidates for disposal. Commercial hazardous waste facilities may also be candidates if no incinerators are on-site. Note that hard-to-treat hazardous wastes must sometimes be shipped across several states to commercial incineration facilities. If you think that the generator of the subject waste transports the waste to a commercial facility, assume that the nearest commercial facility with an appropriate incinerator will handle this waste.

d. Nonhazardous industrial solid waste. Assume that all generators that have incinerators on-site are candidates for treatment of the subject waste. Note that industrial on-site incinerators that are not major sources will not be listed in NEDS, thus may not be identifiable.

Step 4. Determine whether there is information on the capacity and current operating characteristics for the sites listed in Step 3. If so, use this information along with available information on the disposal practices of the generators of the waste to estimate the amount treated at each incinerator. The output of this step will be a list of all candidate incinerators with the estimated amount of the waste treated at each in units of mass per time.

a. Municipal solid waste. The capacities of most municipal incinerators are given in Tables I-2 and I-3, Appendix I. Assume that the candidate incinerators are operating at full capacity unless there is information to the contrary.

b. Municipal sludge. Assume that all of the subject waste generated on-site is treated on-site.

c. Hazardous waste. The capacity of candidate incinerators will be given in the HWDMS retrieval. Assume that all of the waste generated at a given location is treated in the on-site incinerator (if such exists). Likewise, assume that waste from a given source that is shipped to off-site incinerators will be created at one commercial facility, unless the amount generated exceeds the capacity of the off-site incinerator.

d. Nonhazardous industrial solid waste. Use the same assumptions as in Step 4.c.

7.3 Estimating Emissions from Incineration - Stage V Decision Tree

The goal of this stage is to estimate and characterize releases of chemical substances to air from incinerators. In addition, the quantities of incinerator residues must be estimated as well as the chemical concentrations therein. First, the user identifies the parameters that affect emissions and tries to obtain site-specific values for as many as possible. Then the user chooses an approach for estimating emissions using the available information on the design/operating conditions of the incinerator in conjunction with knowledge of the influent waste. The estimates of chemicals emitted to air are ideally used as input to an appropriate model of environmental fate, and the estimates of the residues are used as input in Stage III (Section 2.3.3(1)). The decision tree below provides alternate methods for estimating environmental releases from incinerators in the absence of a validated model. However, the output of this Stage will not be very accurate until accurate emission factors and reliable models are available. Several ongoing EPA projects may provide some of the predictive capacity that is presently lacking for estimating environmental releases from incinerators.

Step 1. Identify suitable approaches for predicting emissions based on available input data and degree of detail and accuracy required.

Relevant design and operating characteristics usually required as input are summarized below in (a) with their expected current availability. Prediction methods are summarized in (b) with their information requirements.

a. The following design and operating characteristics significantly affect the emissions from incinerators. Numerous other factors influence emissions, but their effects on emissions are even more difficult to describe or quantify than those listed below:

- Temperature
- Residence time
- Excess air
- Completeness of mixing

- Type of pollution control
- Waste feed rate
- Method of waste input
- Degree of atomization for liquid wastes

Operation temperatures, residence time, completeness of mixing, and method of waste input are not generally included in currently available inventories and data bases. NEDS and other air data bases (see Appendix A of Volume 2 of this report) contain information on the type of pollution control at sites that are included in the data base. Incinerator capacity or general information on waste feed rate is available through NEDS, HWDMS, and the various inventories (see Table D-5 in Appendix D and Tables I-2 and I-3 in Appendix I). Stack parameters, exit velocity, and facility location are available in the NEDS and other air data bases for sites listed in those data bases.

A report summarizing site-specific operational features of hazardous waste incinerators is currently being developed under EPA-ORD sponsorship; however, this report is not currently available.

Currently no available information summarizes the site-specific data on incinerators on a regional or local level. Some state agencies may have such information in their files. The RCRA Part B, treatment/storage/disposal TSD permit applications for hazardous waste incinerators that will be submitted to the EPA will probably include most of these parameters, as well as trial burn data. However, this information is not expected to be readily accessible in the near future.

b. Currently, there are no well-developed, validated algorithms or models for predicting emissions of chemicals from incinerators. Gaseous and particulate emissions depend on the completeness of combustion, which is a function of the physical and chemical characteristics of the waste in addition to design and operating conditions. The chemical processes that occur within incinerators are not well understood; therefore, without trial burn data or monitoring data, it is difficult to predict chemical emissions. Furthermore, the incomplete combustion of one class of chemicals (such as chlorophenols) may lead to emissions of another class of chemical (such as dioxins). The lack of predictive capability extends to the chemical characterization of ash, scrubber water, and quench water. A model developed for EPA-ORD may be adaptable for this purpose. This model estimates the ability of an industrial boiler to achieve a given destruction efficiency for organic wastes (Wolbach 1982). However, until this or a similar model has been validated for incinerators, the user must have recourse to one of the following prediction methods.

- Use trial burn data, if available, to predict combustion efficiency for a given chemical. A summary of currently available trial burn data is given in Table I-9 in Appendix I. For more details on individual trial burns see Corini et al. (1980). Trial burn data submitted to EPA by applicants for hazardous waste incineration permits may also be available through the appropriate EPA regional office. If data from several trial burns (with different temperatures and residence times) are available, a graph of operating conditions versus combustion efficiency can be plotted and used to roughly estimate combustion efficiency under untested operating conditions. However, there is considerable uncertainty in this approach. Note that this approach requires at minimum a knowledge of operating temperatures and residence time. If these parameters are not known, typical operating conditions for the type of incinerator of interest could be used as surrogate data. Some typical operating data are given in Section 7.1.1. Additional operating data are given in Table I-12 in Appendix I.

- Using available monitoring data on the chemical of interest, compile as many of the following parameters as possible: ranges of emission factors, removal efficiencies, and measured concentrations. Tables 38 and 39 (Section 7.1) present an example of how this was done for a few chemical substances. Use these values as indicators of the typical behavior of the chemicals for which there are data, in the absence of better information. For example, the destruction rate for total organic chlorine (TOCl) given in Table 38 might be applied to any specific chlorinated organic (providing that one takes into account the uncertainty expressed in footnote (d) to that table). Note that the amount of ash produced can be estimated for municipal solid waste and sewage sludge (see Section 7.1.3). This approach requires data on typical design/operating conditions of the incinerators for which there is monitoring information.

- Qualitatively compare the ease of incineration of one chemical for which there is no incineration data with another compound for which there is trial burn, test burn, or monitoring data. Because the ease of incineration is correlated with heat of combustion, chemicals can be ranked by incinerability if their heats of combustion are known. Table I-11 in Appendix I provides the heats of combustion for hazardous wastes listed under Appendix VIII, 40 CFR Part 261. Again, this is a very crude estimation method because the correlation between ease of incineration and heat of combustion has not been extensively tested (USEPA and MITRE

1983). This approach requires knowledge of the heats of combustion for the chemical of interest and the chemical to which it will be compared. Operating temperatures and residence time are also useful in the qualitative comparison.

- For hazardous wastes, in the absence of more reliable information, assume a 99.99 percent destruction and removal efficiency for principal organic hazardous constituents (POHCs) of the waste feed, as required by RCRA regulations (USEPA 1981c).

Step 2. Using the chosen predictive method and input data, estimate emissions from each disposal site receiving the subject waste. The output of this step will be a list of the incinerators with an emissions estimate for each in units of mass per time. Depending on the predictive approach, the output may include concentration and flow.

Step 3. Compare the predicted results from Step 2 to any monitoring data that may be available. If predictions do not correlate with measured values, use best judgment to evaluate the discrepancy. If applicable, calibrate the model and rerun. Then use the estimated emissions as input in the analysis of environmental fate and pathways and the final exposure assessment, as described in Section 5.3 of Volume 2 of this report.

For a complete exposure assessment of incinerator air emissions, stack parameters, exit velocity, geographic coordinates, and emissions may be used as input parameters in an atmospheric transport model, such as ATM-SECPOP, to model concentrations of the chemical to which various receptors located downwind from the release point may be exposed.

8. DEEP-WELL INJECTION

Deep-well injection is a waste disposal method that involves injecting liquid wastes into a permeable rock layer below the surface in geologic basins which may be confined above and below by relatively impervious rock. Improper design or operation can cause contamination of groundwater in other aquifers, resulting in human exposure to chemical substances. Background information on this disposal method is given in Section 8.1, followed by the Stage IV and Stage V decision trees (Sections 8.2 and 8.3). Information is now available on the locations of injection wells and the wastes handled by each well from the Federal Underground Injection Reporting System (FURS), a new computerized data base operated by the Office of Drinking Water at EPA. Estimating releases to groundwater from deep wells is very difficult and subject to considerable error.

8.1 Background Information

This section contains general information on deep-well injection, followed by discussions of (1) the important sources of possible wastes and (2) approaches to estimating releases to groundwater.

8.1.1 General

The governing principle behind deep-well injection is to dispose of a maximum quantity of wastes (including those that are hard to treat, toxic, hazardous, and innocuous) at minimum cost and impact to the environment. Liquid wastes are usually injected into rock formations that are below and isolated from fresh water aquifers. Theoretically, a properly selected reservoir can safely contain the injected wastes, as long as the waste volume does not exceed the available volume of the reservoir and injection pressures do not exceed critical formation pressures (Wiles 1978). However, there is a controversy about whether it is really possible to predict the final disposition of injected wastes; there are numerous site-specific and general data gaps regarding saline aquifer chemistry and the chemical and microbiological reactions within the receiving aquifer. Relationships between waste components, structural geology, mineralogy, and other variables that determine the persistence of injected compounds are not well understood.

Deep-well injection is used for a wide variety of liquid wastes ranging from domestic wastewaters and sewage sludge to hazardous and radioactive wastes. The EPA estimates that there are as many as 650,000 injection wells in the U.S., 85 percent of which are located in the following 22 states: Arizona, Arkansas, California, Colorado, Florida, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Michigan, Mississippi, New Mexico, New York, Ohio, Oklahoma, Pennsylvania, Texas, Utah, West Virginia, and Wyoming (USEPA 1981b).

EPA classifies injection wells in five categories for the purpose of regulation; these categories are listed in Table 40. The classification system is based on the zone of injection (which depends on whether wastes are injected above, into, or below aquifers bearing potable water) as well as the source and type of waste. The injection wells that are likely to be of interest for chemicals assessed under TSCA are in Classes I and IV and constitute a very small fraction of the total population of injection wells. (The vast majority of industrial injection wells are in Classes II and III, which comprise wells used in oil and gas production and mining, respectively.) A recent survey (USEPA 1980g) indicates that only about 268 operating industrial and municipal wells are in Classes I and IV. These are further classified as follows: 1I, industrial disposal well; 1M, municipal disposal well; and 4H, hazardous facility injection. Class 5W may also be of interest, but includes septic tanks and cesspools used for multiple dwellings (it does not include single family residential waste disposal systems).

A summary of injection wells by industry category for Classes 1I, 1M, and 4H is presented as Table 41. Note that most of the wells are operated by the petrochemical, petroleum refining, and oil and gas extraction industries. Table 41 also gives typical well depths for this group. Most of these injection wells are on-site; only nine off-site commercial hazardous waste injection wells were identified in a recent EPA study, all of which are in Regions V and VI (see Table 42). Nationwide, about 2 percent of the hazardous wastes generated are disposed of by deep-well injection (Table 42).

Many kinds of wastes are suitable for deep-well injection. Table J-1 in Appendix J lists all chemicals known to have been injected. Hazardous materials which are persistent in the environment are not recommended for this disposal method because the long storage period required to reduce the hazards to an acceptable level increases the chances that the waste will escape as the result of system failure or migration of fluids. Chlorinated hydrocarbons are not suitable for disposal by deep-well injection (USEPA 1980b). A recent study suggested that the following chemicals are also unacceptable for deep-well injection (Wiles 1978):

- Acrolein
- Arsenic and arsenic compounds
- Cadmium and cadmium compounds
- Carbon disulfide
- Cyanides
- Diazinon and other pesticides
- Fluorides
- Hydrocyanic acid
- Hydrofluoric acid
- Hexavalent chromium compounds
- Mercury and mercury compounds
- Nitrophenol

Table 40. Classifications and Types of Injection Wells

Well Code Class/Type	Primary Function of Injection Wells
Class I	Industrial, municipal, and nuclear storage wells that inject below deepest underground source of drinking water
1I[a]	Industrial disposal well
1M[a]	Municipal disposal well
1X	Other Class I wells
Class II	Oil and gas production and storage-related injection wells
2A	Annular injection well
2D	Produced fluid disposal well
2H	Liquid hydrocarbon storage well
2R	Enhanced recovery injection well
2X	Other Class II wells
Class III	Special process injection wells
3G	*In situ* gasification wells
3M	Solution mining well
3S	Sulfur mining well by Frasch process
3U	Uranium mining well
3X	Other Class III wells
Class IV	Hazardous facility wells that inject into or above an underground source of drinking water
4H[a]	Hazardous facility injection
Class V	All other wells that inject into or above an underground source of drinking water
5A	Air conditioning/cooling water return well
5B	Salinity barrier well
5D	Storm water drainage well
5F	Agricultural drainage well
5G	Other drainage wells
5H	Gaseous hydrocarbon storage well
5R	Recharge well
5S	Subsidence control well
5W[a]	Waste disposal well
5X	Other Class V wells
5N	Nuclear waste disposal or storage well
5T	Geothermal well

[a] Likely to be of most interest in exposure assessments conducted by the EPA Office of Toxic Substances.

Source: EPA Form 7500-48 (11-79).

Table 41. Standard Industrial Classification of Injection Wells
(268 Wells)

Industry	No. of wells	Percentage
MINING (9.3%)		
10 Metal mining	2	0.7
12 Coal	1	0.4
13 Oil and gas extraction	17	6.4
14 Non-metallic mining	5	1.9
MANUFACTURING (80.6%)		
20 Food	6	2.2
26 Paper	3	1.1
28 Chemical and allied products	131	48.9
29 Petroleum refining	51	19
32 Stone and concrete	1	0.4
33 Primary metals	16	5.9
34 Fabricated metals	3	1.1
35 Machinery - except electronics	1	0.4
38 Photographics	3	1.1
TRANSPORTATION, GAS, and SANITARY SERVICES (9.8%)		
47 Transportation service	1	0.4
49 Sanitary service	23	8.6
50 Wholesale trade - durable	1	0.4
55 Auto dealers and service	1	0.4
OTHER (0.4%)		
72 Personal service	1	0.4

WELL COMPLETION DEPTHS
(262 Wells)

Depth[a]	No. of wells	Percentage
0 - 1,000	20	7.6
1,001 - 2,000	56	21.4
2,001 - 3,000	33	12.6
3,001 - 4,000	34	12.8
4,001 - 5,000	39	14.8
5,001 - 6,000	44	16.7
6,001 - 7,000	18	7.2
7,001 - 8,000	12	4.8
8,001 +	3	1.2

[a] Units were not given in source, but they are probably feet.

Source: USEPA 1980g.

Table 42. Commercial Off-site Hazardous Waste Disposal Facilities Offering Deep-well Injection Services in 1980 by EPA Region

EPA Region	No. of facilities	Amount of waste handled (thousands of wet kkg)	Percentage of off-site waste handled[a]	Percentage of total waste handled[b]
I	0	0	0	0
II	0	0	0	0
III	0	0	0	0
IV	0	0	0	0
V	1	152	11.4	2.3
VI	8	635	61.7	6.0
VII	0	0	0	0
VIII	0	0	0	0
IX	0	0	0	0
X	0	0	0	0
TOTAL	9	788	13.0	1.9

[a] Percentage of total off-site handled waste treated by deep-well injection.
[b] Percentage of total waste generated in region that is disposed of at off-site injection wells.

Source: USEPA 1980b.

8.1.2 Information Resources Useful in Assessing the Potential for Exposure from Injection Wells

Injection wells will be closely regulated under new federal and state regulations. EPA is requiring the states to develop programs to prevent contamination of groundwater by injection wells for the Underground Injection Control (UIC) program brought about by the Safe Drinking Water Act. As a result of the concern over the potential for groundwater contamination from injection wells, there is considerable site-specific information on existing wells. Under the UIC program, a new computerized data base is available to keep track of injection wells. This data base is called the Federal Underground Injection Reporting System (FURS) and contains data on injection wells in the U. S. This data base lists all wells and includes information on the location, operational status, and well class for states that do not have an approved UIC program. Because the class is somewhat indicative of the types of waste that it receives (see Table 40), this inventory will be useful in exposure assessments. Also, Region VI already has its own computerized injection well data base, which contains detailed site-specific data. Until the UIC program is fully operative, hazardous waste injection wells (Class IV) will have to submit RCRA permit applications. Therefore, the Hazardous Waste Data Management System (HWDMS) (see Section 2.3.3(4) and Exhibit D-1 in Appendix D) contains information on the location, SIC Code, and proposed capacity for hazardous waste injection wells. State agencies are currently the best source of site-specific geological, hydrological, and design data for injection wells not located in Region VI. These data will generally have to be retrieved manually.

8.1.3 Modeling Releases to Groundwater

See Section 3.1.3 for a general discussion of modeling groundwater contaminated from waste disposal sites and Volume 5 of this methods development series for more information on groundwater modeling. The modeling of groundwater contamination via deep-well injection is even more difficult than for previously mentioned land disposal methods because of the considerable difficulty and expense involved with obtaining information to run such models. As in most cases involving groundwater models, the assistance of a hydrogeologist will be required. Should accurate and concise information be a necessity, then the assistance of a company such as GeoTrans Inc., Reston, Virginia, which specializes in groundwater studies, may be required.

The EPA has developed an approach to regulating injection wells that has the potential to serve as a coarse screening tool in determining which wells may present the greatest risk of groundwater contamination. The regulations prescribe that a "zone of endangerment" be designated for each injection well. Zone of endangerment is defined as the theoretical circular area (centered on the well) in which the pressures in the injection zone may cause the migration of the injection and formation fluid into an underground source of drinking water (USEPA 1981d). If this radius could be accurately determined for any injection well (which is questionable), then the potential for contamination of groundwater supplies could be estimated qualitatively. A modified This Equation that can be used to calculate the zone of endangerment is given as Table J-2 in Appendix J. Computation of the zone of endangering influence requires the following parameters:

- Hydraulic conductivity of the injection zone (length/time)
- Thickness of the injection zone (length)
- Time of injection (duration/time)
- Storage coefficient (dimensionless)
- Injection rate (volume/time)
- Observed original hydrostatic head of injection zone (length), measured from the base of the lowest Underground Source of Drinking Water (USDW)
- Hydrostatic head of the USDW (length), measured from the base of the lowest USDW
- Specific gravity of the fluid in the injection zone (dimensionless)

These parameters are representative of the parameters commonly used in groundwater modeling. When considering whether to issue a permit to an applicant, EPA or the responsible state agency will review available site-specific data on the number and location of all wells, surface waters, springs, mines, quarries, location of USDWs, residences, roads, and geology in the zone of endangerment. These same parameters, which will be available in agency files, should be considered when the potential for exposure from a given injection well is assessed, because the primary route of exposure will be via drinking or other contact with water from USDWs. Determining the appropriate groundwater models for site-specific estimates of emissions from injection wells is beyond the scope of this methodology and will best be left to the modelers. Good sources of information on the multitude of available groundwater models include the EPA Ground Water Models Clearinghouse, a computerized data base that provides summaries of the important features of 300 models (see Appendix A) and a groundwater model review report by the EPA Office of Solid Waste (USEPA 1982a). See Section 8.3 for information on a model that has been used to approximate pollutant migration from injection wells.

8.2 Allocating Waste Streams to Individual Injection Wells - Stage IV Decision Tree

In this stage, the available information on the locations of injection wells of the class appropriate for the waste stream of interest will be reviewed, in order to select the individual wells likely to receive the waste stream of interest. Then the amount of the waste stream of interest disposed of in each candidate well will be determined. The body of information upon which these decisions are made is extensive.

Step 1. Determine whether disposal of the waste will be limited to certain classes of injection wells. The output of this step will be a list of the relevant classes.

Consider the characteristics of the waste and its origin. The classification and type of injection well receiving the waste will depend on the nature and source of the waste. Consult Table 40 to determine the class of well appropriate for disposal of the waste. If there is uncertainty over which type of well is appropriate, consult USEPA 1981d for a more complete description of the well classification system.

Step 2. If applicable, determine the percentage of the waste that will be disposed of on-site versus off-site. The output of this step will be the list of well classes compiled in Step 1 to which the percentage of on-site versus off-site disposal has been added for each well class. This information will be useful in identifying wells that are candidates for disposal of the waste (Step 3).

Municipal disposal wells will be, by definition, off-site, but are probably located at or near a treatment works POTW. Waste disposal injection wells will also be off-site, since they are usually the repository for wastewaters from multiple dwellings. Most industrial injection wells are on-site. The only off-site commercial facilities known to exist are those few that handle hazardous wastes (see Table 42).

For site-specific information on whether disposal will be off-site, conduct a retrieval of the (FURS) and see whether any of the generators of the waste stream of interest have injection wells on-site. Supplement this with a Hazardous Waste Data Management System (HWDMS) retrieval (see Section 2.3.3(4) and Exhibit D-1 in Appendix D). If the information from these two sources is insufficient, contact the agencies responsible for the Underground Injection Control program (UIC) in the state(s) of interest. Assume that all generators with on-site wells that are classified appropriately will dispose of the waste on-site if it is suitable for injection (see Section 8.1). Otherwise, use best judgment to determine whether the waste might be disposed of in off-site injection wells, based on knowledge of the waste disposal practices of the industry for similar wastes.

Note that some generators of difficult-to-treat hazardous wastes have to ship them across the U.S. for disposal in commercial injection wells. One novel use of the HWDMS in this regard would be to conduct a retrieval of all hazardous waste injection wells, requesting the auxiliary data on waste codes treated. Even though these data are considered unreliable for quantitative purposes (see Section 2.3.3(4)), they will provide general information on the kinds of wastes that a given facility might accept for deep-well injection.

Step 3. **Based on the information in Steps 1 and 2, and available inventories (computerized or other) of disposal facilities, identify the injection wells that are candidates for the disposal of the waste. The output of this step will be a list of the candidate injection wells.**

The FURS retrieval combined with the HWDMS retrieval and information from state agencies will provide a list of all on-site injection wells. The Needs survey data base retrieval (see Sections 2.3.3(3) and 6, and Exhibit H-1 and Table A-8 in Appendix H) will indicate which POTWs use this disposal method. Assume that all generators with on-site wells of the appropriate class will dispose of the waste on-site. Consider the discussion in Step 2 in deciding which off-site wells may receive the waste.

Step 4. **Determine whether there is information on the capacity and current operating characteristics for the candidate sites listed in Step 3. Use this and any other relevant information to estimate the amount of the waste that will be disposed of at each facility in units of mass/time. The output of Stage IV will be the Step 3 list to which individual amounts of disposed-of waste have been added for each injection well.**

Assume that all of the waste generated at a given source will be disposed of in one injection well, unless it exceeds the capacity of the well. Capacities of hazardous waste injection wells will be given in the HWDMS retrieval. Additional information on capacity may be available from the state agencies in charge of the UIC program.

8.3 Estimating Releases from Injection Wells - Stage V Decision Tree

This decision tree presents the available approaches to estimating the releases of the chemical substance to groundwater from deep-well injection. As stated previously, the modeling of contaminent migration from injection wells is very difficult and probably best performed by hydrogeologists. Many variables that affect the contamination potential are either little understood or difficult to quantify on a site-specific basis.

Step 1. **a. Identify the important design and operating characteristics of injection wells that affect releases to groundwater.**

See Section 8.1.3 for the list of parameters that govern thephysical behavior of injected fluids. In addition to these factors, the type of casing and cementing used in constructing the well is critical because it must prevent the movement of fluids into or between other sources of drinking water. Therefore, it must be able to withstand all of the normal stresses associated with use, including injection pressures, corrosiveness of injected fluid, and fluctuating temperatures.

b. Determine which of the parameters listed in 1.a are known for the sites of interest based on accessible computerized data or other readily available data.

Information on most of the parameters discussed in Step 1.a will be available in the application submitted to the EPA (or to the responsible state office) after the UIC program is operable, but is not generally available in computerized form at this time. The EPA Region VI data base probably contains most of the important data already.

c. Identify which of the parameters listed in 1.a can be obtained from existing files at regional EPA offices and responsible state solid waste agencies when not available from the sources listed in 1.b.

Many state agencies responsible for permitting injection wells, especially those states that have numerous injection wells, will probably have most of these data in their files. Some of these data have also been collected for industrial wells in EPA surveys (see Reeder et al. 1977b) and can be obtained from such reports.

Step 2. a. Identify and list the approaches that are available for predicting environmental releases based on the design/operating characteristics of the wells.

As discussed in Sections 3.1.3 and 8.1.3, numerous groundwater models have been developed. The Land Disposal Division of the EPA Office of Solid Waste is developing a set of test problems for evaluating new mathematical models of saturated zone leachate migration with respect to their utility in predicting pollution migration from land disposal and injection wells. They have used a model program called SWIP (Survey Waste Injection Program) developed by USGS (Mercer et al. 1981). This model was developed to investigate problems associated with the disposal of wastes in deep wells and is applicable for modeling the transport of momentum, energy, and contaminant mass in porous media associated with deep-well injection or other sources. Appendix J-3 presents a summary of this model. While other models may also be applicable for use in injection wells, this model is used here as an example of the input requirements. Modeling of deep wells is highly complex, and model selection is beyond the scope of this methodology.

b. Identify the site-specific design/operating characteristics required for input by the model of choice. Determine whether these data are readily available. If not, determine whether there are surrogate values that can be used in place of the site-specific parameters.

As an example of the data elements that may be required, the following list gives input parameters that are used for various solutions available using SWIP:

- Aquifer thickness (length)
- Aquifer compressibility (assumed 0.0/psi in one test problem)
- Porosity (unitless)
- Water unit weight (62.4 lb/ft3)
- Water compressibility (0.00115/psi)
- Hydraulic conductivity (length/time)
- Initial pressure (psi)
- Wellbore radius (length)
- Reservoir exterior radius (length)
- Effective molecular diffusivity (area/time)
- Velocity (length/time)

The parameters needed in SWIP will generally be available in standard references and state and EPA files once the UIC is operable; many state agencies may already collect the requisite information. Because of the highly site-specific nature of groundwater hydrology, it is generally thought that the magnitude of error introduced by attempting to use surrogate data renders predictions based on surrogate data of little use. (Even with accurate site-specific data, groundwater models make simplifying assumptions that may not be warranted.) Note that this model does not describe biological or chemical processes associated with deep-well disposal.

Step 3. **Input the data into the chosen model and run the model to produce an evaluation of chemical releases.**

If an appropriate model is applied correctly and accurate site-specific data are available, the groundwater model can provide various types of output data, the most important of which are contaminant concentrations that may lead to or be a drinking water source.

Step 4. **If monitoring data are available, compare them with the model predictions to test the accuracy of the model application.**

One possible source of data is the UIC program which will require installation and periodic sampling of monitoring wells. These monitoring data will be submitted to the state agencies in charge of the authorized state UIC programs. However, it is not known whether these data can be retrieved in a computerized format.

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APPENDICES

GUIDE TO APPENDICES

These appendices provide information intended to supplement "Methods for Assessing Exposures from Disposal of Chemical Substances," Volume 3 of the series "Methods for Assessing Exposures to Chemical Substances." The format herein is organized into eleven appendices (Appendices A through K) based on subject matter. The appendices comprise a wide range of information resources including lists of useful contacts at state and federal agencies, sample data on waste generation rates and quantities of wastes handled by various disposal practices, sample inventories of existing disposal facilities, generic data on design and operation of disposal facilities, data on emission factors, and information on useful data bases and models.

The appendices assembled herein are intended to acquaint the user with key information resources that may be useful in assessing exposures to chemicals resulting from disposal. They are not meant to be the sole or even the major information resource for such exposure assessments; the body of information of potential use in assessing exposures from disposal is far too large and varied to include here. Rather, these appendices should be used to supplement the information resources described in the main text when information needed for a given exposure assessment is needed.

Many of the sample tables included in the appendices were reproduced from the original source with little or no modification so that the user might become familiar with the content, presentation, and limitations of available information resources. In many cases, the user will have to consult the original source to interpret or expand upon the data given in the appendices.

A description of the kind of information provided in each appendix is provided below.

Appendix A. This appendix summarizes the models and data bases that are discussed in the methodology. The data bases are expected to be important tools in evaluating exposure from disposal of chemical substances. Because the state of the art in model development does not generally meet the predictive needs of this methodology, the models in Appendix A are not necessarily suitable for exposure assessment at the present time.

Appendix B. This appendix (Tables B-1 and B-2) is a summary of published information on waste generation collected from selected state solid waste agencies in the course of developing these methods. Although these reports were only collected from a sampling of states, they are expected to be representative of the kinds of information available from all states. As might be expected, the amount of information maintained by state solid waste agencies varies markedly. Depending on the state, information on one or more of the following topics may be available:

- Locations of disposal sites
- Kinds and quantities of wastes accepted
- Types and quantities of industrial wastes generated
- Information on on- versus off-site disposal
- Analyses of industrial waste streams.

Thus, state solid waste agencies may provide useful generic and/or site-specific data for assessing environmental releases from disposal, particularly for Stages II, III, and IV. See Table D-3 for a list of the state solid waste agencies.

Appendix C. This appendix is a collection of compiled data on waste generation and disposal in the chemical manufacturing and petroleum refining industries. Table C-1 presents a summary of the total quantities of hazardous waste generated and the quantities disposed of off-site for the plastics, industrial organic chemicals, petroleum refining, and petroleum re-refining industries. This table is followed by more detailed information on these industries, including typical waste constituents, and quantities of wastes handled by various disposal practices. These tables provide generic industry-specific data that are useful in estimating overall waste quantities (Stages I and II), and likely disposal methods (Stage III) for industrial solid wastes. In addition, these generic data can be helpful in allocating quantities of waste to individual disposal sites (Stage IV). For instance, if Appendix C indicates that the industry of interest generally uses on-site landfills, we can assume that all solid waste generated on-site is disposed of in on-site landfills and allocate waste quantities accordingly. The user should be aware of the following when using Appendix C:

(1) Although the information in these reports is generally the most comprehensive published material available, the data may not represent the current waste disposal "picture."

(2) Information similar to the data in Appendix C is available for all industries listed in Table 9 of this report.

Appendix D. This appendix is a collection of information from sources that are useful in determining the likely disposal methods for a given type of waste containing chemical substances (Stage III). It should be stressed, however, that useful information sources for Stage III will also be found in the other appendices. Exhibit D-1 summarizes pertinent features of the Hazardous Waste Data Management System (HWDMS) data base, which provides useful input to Stage III and Stage IV procedures for hazardous wastes. Tables D-1 and D-2 provide useful generic data for determining how much wastewater will be treated by POTWs. Table D-3 is a list of appropriate state solid waste agencies which should be consulted for state-specific waste disposal information. Table D-4 gives the treatment/storage/disposal codes used in the Hazardous Waste Data Management System (HWDMS) data base; an HWDMS retrieval may be an important source of Stage III information. Table D-5 is a summary of typical disposal practices for most of the individual hazardous waste listed under RCRA. Table D-6 provides information useful in determining whether a given hazardous waste is likely to be incinerated and in determining incinerator types. Table D-7 summarizes selected HWDMS data on the disposal of hazardous waste. Finally, D-8 lists the industries subject to effluent guidelines and pretreatment standards. Knowledge of pretreatment standards may be useful when estimating the contribution of toxic chemicals to POTWs from industries.

Appendix E. This appendix is a collection of data related to waste disposal in landfills and by land treatment, which will be useful in Stages IV and V and for modifying first-cut Stage III estimates. Table E-1 is a summary of the U.S. population distribution in relation to wetlands (environmentally sensitive areas). This information could be used in the absence of better data to roughly estimate the proportion of landfill acreage located in areas with high water tables on a statewide or nationwide basis. (This would be useful Stage V information for the modeling of emissions from landfills in large-scale exposure assessments.) Table E-2 presents information on the relative distribution of landfills of varying capacities as well as information on the number of landfills with National Pollution Discharge Elimination System (NPDES) permits by state. Table E-3 is a summary of the input data requirements for the SESOIL model. Tables E-4 and E-5 summarize the geographic distribution and industrial classification, respectively, of hazardous waste land treatment facilities identified in a recent survey. These data, together with the map of land treatment facilities provided in Figure E-1, are essential input to Stage IV and Stage V procedures for land treatment facilities. Figure E-2 is a bar graph summary of the size distribution of land treatment facilities that can be used to extrapolate generic data on land treatment capacity when site-specific data are either not available or not required.

Appendix F. This appendix presents auxiliary information on groundwater that may be useful in the Stage V modeling of chemical releases from landfills, land treatment sites, surface impoundments, and injection wells. Table F-1 is a list of computerized groundwater data bases that provide information on depth of water table for various areas of the U.S. Table F-2 is a list of state groundwater geologists, who are useful contacts when detailed information on groundwater is required for modeling purposes. Figure F-1 provides a gross picture of the distribution of wetlands nationwide. In the absence of better information, this map may serve as a source of very general information on relative depths of groundwater.

Appendix G. This appendix provides information on surface impoundments useful in Stage V. Tables G-1 and G-2 give the relation between characteristics of the saturated and unsaturated soil zones beneath surface impoundments and the SIA (Surface Impoundment Assessment) rating system. This information will be useful if a SIA data base retrieval is conducted to obtain data necessary for modeling.

Appendix H. Appendix H is a compilation of information on POTWs that may be helpful in predicting emissions of chemical substances in the absence of a suitable POTW model. Exhibits H-1 and H-2 provide summary descriptions of the Needs Survey and IFD data bases, both of which may be useful in estimating chemical releases from POTWs. Tables H-1 through H-7 summarize the data on priority pollutants in POTW waste streams from the most comprehensive study available (Burns and Roe 1982). Tables H-1 through H-4 give the results of sampling data for priority pollutants at representative secondary POTWs; the media sampled include POTW influent, secondary effluent, and raw sludge. Tables H-5 and H-6 summarize the treatment efficiencies of priority pollutants by the secondary treatment method. Table H-7 provides data on typical concentrations of priority pollutants in POTW sludge when not detected in influent (which gives some indication of the tendency of pollutants to be concentrated in sludge). Table H-8 lists the wastewater and sludge treatment methods that are included in the Needs Survey data base; this information will be useful in designing a Needs Survey retrieval for Stages III through V.

Appendix I. A considerable body of data on incineration is represented in this appendix, which will be useful in Stages III through V. Figure I-1 and Tables I-1 through I-5 provide information on numbers and/or locations of various types of incinerators in the U.S. Tables I-6, I-7, I-9, I-10, I-13, and I-14 give data on air releases for selected chemicals that exemplify the kind of data that will be useful in the absence of a suitable model for predicting emissions from incineration. Table I-8 rates the incineration potential of RCRA-listed hazardous wastes and gives the suitable incinerator types for each waste; this information will be useful in Stage III and in Stage IV. Table I-11 lists the heats of combustion for RCRA-listed hazardous constituents; these data can be used in "gross" Stage V emissions estimates, as discussed in Section 7.3. Table I-12 presents the typical operating ranges (which may be needed in Stage V models) for various types of hazardous waste incinerators.

Appendix J. Some information on waste disposal by deep-well injection is compiled in Appendix J. Table J-1 lists compounds that are known to have been disposed on in injection wells; this information may be useful in Stage III determinations. Table J-2 presents the modified Theis equation, which may be useful in Stage V estimates. Finally, Table J-3 gives a summary of the SWIP model.

Appendix K. A list of conversion factors that may be useful in conducting the procedures recommended in this volume is presented in Appendix K.

APPENDIX A

INFORMATION RESOURCE MATRIX: USEFUL MODELS AND DATA BASES

Appendix A. Information Resource Matrix: Useful Models and Data Bases[a]

			RELEVANT DISPOSAL METHOD AND STAGE OF METHODOLOGY												
			Stage	Landfill		Land treatment		Surface impoundment		POTW		Incineration		Deep-well Injectio	
Acronym	Name	Responsible EPA Office/reference or contact	III	IV	V	IV	V	IV	V	IV	V	IV	V	IV	V
–	Air emission models for surface impoundments	Hwang 1982							●						
–	Air emissions models for industrial boilers	Wolbach 1982											●		
–	Air emissions models for landfills	Hwang 1982, Shen 1981			●										
AT123D	Analytical Transient 1-, 2-, and 3-Dimension Simulation of Waste Transport in the Aquifer System	Yeh 1981			●		●		●						●
–	Air emissions models for land treatment	Hwang 1982, Thibodeaux and Hwang 1982					●								
–	DRAINMOD/DRAINFIL	Skaggs 1982[b]			●		●		●						
FURS	Federal Underground Injection Reporting System (database)	EPA Office of Drinking Water												●	●
–	Groundwater data bases[c]	USGS/USDA 1979			●		●		●						●
–	Ground Water Models Cleaning house	Tom Malone/Phone 317-283-9421			●		●		●						●
HELP	Hydrologic Evaluation of Landfill Performance	Perrier and Gibson 1980[b]			●										

Appendix A. (Continued)

Acronym	Name	Responsible EPA Office/reference or contact	RELEVANT DISPOSAL METHOD AND STAGE OF METHODOLOGY												
			Stage	Landfill		Land treatment		Surface impoundment		POTW		Incineration		Deep-well Injection	
			III	IV	V	IV	V	IV	V	IV	V	IV	V	IV	V
HWDMS	Hazardous Waste Data Management System (data base)	EPA Office of Solid Waste	●	●	●	●	●	●	●			●	●	●	●
IFD	Industrial Facilities Discharge (data base)	EPA Office of Water Regulations and Standards	●						●	●	●				
NEDS	National Emissions Data System	EPA Office of Air Quality Planning and Standards										●	●		
Needs	1980 Needs Survey (data base)	EPA Office of Water Program Operations/ USEPA 1981[e]	●			●		●		●	●			●	
PCS	Permit Compliance System (data base)	EPA Office of Water Enforcement and Permits							●	●	●				
PCLTF	Post-Closure Liability Trust Fund	USEPA 1982d[b]			●		●		●						
PRZM	Pesticide Root Zone Model	EPA Office of Research and Development			●		●								
-	Rapid Assessment of Groundwater Contamination Under Emergency Response Conditions	Donigian et al. 1983			●		●		●						

Appendix A. (Continued)

			RELEVANT DISPOSAL METHOD AND STAGE OF METHODOLOGY												
			Stage	Landfill		Land treatment		Surface impoundment		POTW		Incineration		Deep-well Injection	
Acronym	Name	Responsible EPA Office/reference or contact	III	IV	V	IV	V	IV	V	IV	V	IV	V	IV	V
–	Release Rate Compilations[b]	SCS Engineers 1982[b]			●		●		●						
RWSTM	Random Walk Solute Transport Model	Prickett et al. 1981			●		●		●						●
SESOIL	A Seasonal Soil Compartment Model	EPA Office of Toxic Substances/ Bonazountas and Wagner 1981, Bonazountas et al. 1981, Wagner and Bonazountas 1981					●		●						
SIA	Surface Impoundment Assessment	EPA Office of Drinking Water/USEPA 1978, USEPA 1980e						●	●						
SWIP	Survey Waste Injection Program (model)	EPA Office of Solid Waste/Mercer et al. 1981													●

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[a] This list is limited to models and data bases useful in steps leading to etimating releases to the environment from waste disposal. See Volume 2 of this report for more information on models and data bases useful in the environmental pathways and fate analysis and subsequent steps in the exposure assessment. See Volume 5 of this report for more information on groundwater models.

[b] Cited in Versar 1983.

[c] See Table F-1 in Appendix F for a list of these data bases.

APPENDIX B

SUMMARY OF INFORMATION COLLECTED FROM STATE SOLID WASTE AGENCIES

Exhibit B-1. Selected Reports on Waste Generation and Disposal Prepared by State Solid Waste Agencies*

The Illinois Environmental Protection Agency distributes a report entitled the "Illinois Industrial Waste Survey" (1980) summarizing the results of a multivolume study. The report summarizes quantities of waste types generated by each SIC group in the state, the percent distribution of waste types to different disposal methods (on-site and off-site), and other data.

The Michigan Energy Administration, Department of Commerce, distributes four reports analyzing waste stream composition and quantities received by municipal landfills in different regions of the state. Total quantities and per capita estimates are provided.

The Kansas Department of Health and Environment distributes a report entitled "A Survey of Hazardous Waste Generation and Disposal Practices in Kansas" (two volumes plus summary), listing the waste types for each industry and quantities disposed of by each method.

The Delaware River Basin Commission (West Trenton, N.J.) distributes a summary report of their "Industrial Exotic Waste Program Findings, Conclusions, and Recommendations" (1979), analyzing industrial waste streams and disposal practices in New Jersey. The report includes a list of all facilities in the area known to accept industrial waste.

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*This list is based on a limited sampling of state solid waste agencies. This information is provided in order to acquaint the user with the kind of information sometimes available on the state level.

Exhibit B-2. State Inventories of Disposal Facilities*

The California State Solid Waste Management Board maintains a computerized data retrieval system whereby one may determine types and volumes of waste disposed, site-specific operational characteristics of facilities, and their names and locations. Use of this data base should supply most of the data requirements for the methodology for any site in California.

The Missouri Department of Natural Resources distributes a report entitled "Facilities for Solid Waste Disposal and Processing" listing contacts in state regional offices, names and locations of all permitted sanitary landfills, processing facilities and transfer stations for resource recovery, and permitted special waste disposal facilities. This state also distributes "Facilities Available to Missouri Industry for Hazardous Waste Management", listing hazardous waste landfills, incinerators, treatment, and recycling facilities.

The Kansas Department of Health and Environment distributes a "Directory of Sanitary Landfills, Solid Waste Transfer Stations, and Collectors in Kansas." The May, 1981 issue not only lists names and locations of all permitted facilities but also total quantity of solid waste received by each facility for 1978, 1979, and 1980. Kansas also distributes "A Survey of Resource Recovery Markets and Hazardous Waste Management Facilities" listing names and locations of each such facility in the state, 23 waste exchanges throughout the country, addresses and phone numbers of solid waste agencies for all states, trade associations and other sources of information and assistance, and a list of all hazardous waste disposal facilities in 18 states in the Midwest.

The Kentucky Department of Natural Resources and Environmental Protection distributes a list of names and locations of all permitted landfills and sanitary landfills in the state.

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*This list is based on a limited sampling of state solid waste agencies. This information is provided in order to acquaint the user with the kind of information sometimes available on the state level.

APPENDIX C

INFORMATION ON WASTE DISPOSAL PRACTICES OF SELECTED INDUSTRIES

Table C-1. Summary of Hazardous Waste Generation and Disposal in 1980 for Selected Chemical Manufacturing and Petroleum Refining Industrial Segments by EPA Region (All quantities in thousands of wet kkg)

EPA Region	SIC 282: plastic materials, synthetics[a]		SIC 286, 2879: industrial organic chemicals and agricultural chemicals, NEC[b]		SIC 2911: petroleum refining[c]		SIC 2992: petroleum re-refining[d]	
	Total	Off-site	Total	Off-site	Total	Off-site	Total	Off-site
I	31	unk	9	<1	0	0	0	0
II	108	unk	689	24	76	23	46	41
III	98	unk	1,459	51	152	46	13	12
IV	192	unk	2,130	74	57	17	33	30
V	131	unk	333	12	323	97	61	55
VI	131	unk	8,014	280	836	251	42	38
VII	8	unk	81	3	95	29	4	4
VIII	0	unk	0	0	57	17	4	4
IX	38	unk	333	12	247	74	11	10
X	38	unk	18	1	57	17	4	4
TOTAL	769[e]		13,066[e]	458	1,901[e]	571	218[e]	198
Annual growth rate	6.6%		5.0%		0%		9.0%	
Disposal practices	landfill, incineration		all methods		lagoon, landfarm, landfill, deepwell injection		landfill	

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[a] Waste consists of miscellaneous organics (phenols, resins), solvents, and wastewater treatment sludges.

[b] Sixty-five separate waste streams included in this estimate.

[c] Estimate includes waste streams K048, K049, K050, K051, as well as nine other streams consisting of spent feedstocks, miscellaneous sludges, and tank bottoms.

[d] Estimate includes three waste streams; acid sludges, caustic sludges, and spent clay.

[e] Range of this estimate is ± 25%.

Source: USEPA 1980b.

Table C-2. Hazardous Waste Constituents - Petroleum Rerefining (SIC 2992)

Hazardous waste constituents									
Waste type	Constituents Mg/year, 1977 (dry basis)								
	Acid	Oils[b]	As	Ba	Cd	Cr	Cu	Pb	Zn
Acid sludges	11,600	13,000	2.4	37.8	0.8	0.4	3.8	581	81
Caustic and other sludges	. . .	5,600	0.8	15.5	0.4	0.6	1.9	232	32
Spent clay	. . .	4,000	. . .	. . .	. . .	. . .	. . .	85	. . .
Totals	11,600	22,600	3.2	53.3	1.2	1.0	4.7	898	113

[b] Oils include petroleum oils, polymers, polar compounds, and asphalt.

Source: Van Noordwyk 1980.

Table C-3. Disposal Practices - Petroleum Rerefining

Industrial hazardous waste quantities by disposal method								
		Disposal methods Mg/year, 1977 (dry basis)[a]						
Waste type	Total hazardous waste Mg/year, 1977 (dry basis)	Landfill, onsite		Landfill, offsite				Recycled/reused
				Public		Private		
		Treated[b]	Untreated	Treated	Untreated	Treated	Untreated	Onsite and offsite
Acid sludges	38,300	6,200	. . .	3,700	900	20,000	7,900	. . .
Caustic and other sludges	15,400	. . .	. . .	. . .	. . .	. . .	. . .	15,400
Spent clay	20,190	1,900	. . .	4,100	1,000	6,500	6,600	. . .
Totals	74,300	8,100	. . .	7,800	1,900	26,500	14,500	15,400

[a] Dry basis approximates wet basis since caustic sludges contain only a slight amount of moisture.

[b] Treated means acid neutralization by mixing with cement dust, lime, or other alkaline materials.

Source: Van Noordwyk 1980.

Table C-4. Hazardous Waste Constituents - Petroleum Refining

Waste types and hazardous constituents	
Waste types	Constituents
Leaded gasoline sludge	Organic lead vapors, phenols, and heavy metals
Cooling tower sludge	Heavy metals
Crude tank bottoms	Oil and heavy metals
Dissolved air flotation (DAF) float	Oil and heavy metals
Exchanger bundle cleaning sludge	Oil and heavy metals
Slop oil emulsion solids	Oil and heavy metals
Once-through cooling water sludge	Oil and heavy metals
Waste bio sludge	Oil and heavy metals
Storm water silt	Oil and heavy metals
Spent lime from boiler feedwater treatment	Oil and heavy metals
Kerosene filter clays	Oil and heavy metals
Nonleaded tank bottoms	Oil and heavy metals
API separator sludge	Oil and heavy metals
Lube oil filter clays	Oil and heavy metals
FCC catalyst fines	Heavy metals
Coke fines	Heavy metals
Neutralized hydrofluoric acid alkylation sludge	Oil and heavy metals

Source: Van Noordwyk 1980.

Table C-5. Disposal Practices - Petroleum Refining

Industrial hazardous waste quantities by disposal method
Mg/year, 1977 (wet basis)

Method	Onsite	Offsite	
		Public	Offsite
Landfill	355,000	428,000	107,000
Lagoon	284,000	. . .	289,000
Landspread	334,000	. . .	4,000
Incinerate	40,000	. . .	
Totals	1,013,000	428,000	400,000

Total petroleum refining industry hazardous waste: 1,840,000
Mg/year, 1977 (wet basis)

Source: Van Noordwyk 1980.

Table C-6. Disposal Practices - Organic Chemicals (SIC 2861, 2865, 2869, except 28694)

Industrial hazardous waste quantities by disposal method Mg/year, 1977 (wet basis)

Method	Quantities	
	Onsite	Offsite[a]
Landfill	483,000	113,000
Incineration	2,250,000	51,000[b]
Controlled	(699,000)	. . .
Uncontrolled	(1,550,000)	. . .
Deep well	6,540,000	. . .
Biological treatment/lagoon	565,000	. . .
Recovery	267,000	. . .
Landfarm	NA[c]	. . .
Totals	~10,100,000	164,000[d]

Total organic chemicals industry hazardous waste: 10,300,000 Mg/year, 1977 (wet basis)

[a] Predominantly private except for minor portions (<20%) disposed of legally, illegally, or unknowingly in municipal landfills and/or incinerators

[b] Largely controlled (>90%) due to regulations which contract incinerator operations must satisfy to destroy a variety of wastes

[c] Not available

[d] The amount given here is believed to be low. The actual quantity disposed of offsite is believed to be between 5 and 15 percent of the total.

Source: Van Noordwyk 1980.

Table C-7. Hazardous Waste Treatment/Disposal Methods - Selected Organic Chemical Plants

Treatment and Disposal Location/Process	Number of Hazardous Waste Streams	% of Total Number of Hazardous Waste Streams	Annual Volume Actual Tons*	Percent of Total Annual Actual Tons	Annual Volume Estimated Dry Tons*	Percent of Total Annual "Dry" Tons
On-Site						
Landfill	55	31.6	20,723	4.7	20,723	14.8
Incineration	(58)	(33.3)	(97,759)	(21.9)	(97,759)	(69.7)
Controlled	31	17.8	30,411	6.8	30,411	21.7
Uncontrolled	27	15.5	67,348	15.1	67,348	48.0
Deep Well Injection	10	5.7	282,889	63.6	2,829	2.0
Biological Treatment/Lagoon	13	7.5	24,325	5.5	243	0.2
Recovery	21	12.1	11,670	2.6	11,670	8.3
Landfarm	1	0.6	NA**	NA	NA	NA
Contractor						
Landfill	9	5.2	5,100	1.1	5,100	3.6
Incineration	7	4.0	2,100	0.5	2,100	1.5
TOTAL	174		444,566		140,424	

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*metric tons

** NA indicates Not Available

Source: TRW 1975.

Table C-8. Hazardous Waste Treatment/Disposal Methods at Selected Organic Chemical Plant Sites[a]

Individual Hazardous Waste Stream	Disposal Process	Actual Quantity, metric tons/yr
Liquid tars, still bottoms and process residues	Incineration, uncontrolled, energy recovery	17,800
Liquid tars and oils (still bottoms)	Landfill	300
Liquid tars (still bottoms)	Incineration, controlled	300
Waste water, condensate	Incineration, controlled	7,600
Liquid tars	Landfill	50
Liquid tars and oils	Landfill	140
Liquid, tars and oils	Landfill	90
Liquid, tars and oils	Landfill	50
Liquid, oils (distillation residue)	Landfill	50
Semi-solid phenolic wastes	Landfill, drummed	70
Solid, spent activated carbon	Recovery	Not Available
Liquid process wastes (phenols, alcohols, etc.)	Incineration, controlled	1,600
Liquid, dispersed in water organics[1] with metal catalyst	Incinerator controlled[2] Landfill, drummed	21,800
Liquid, mixed process waste[3] slurry in water	Deep well	254,000[4]
Liquid tars, reactor byproduct	Incinerator, uncontrolled	1,800
Liquid tars, byproduct	Incinerator, uncontrolled	500
Liquid organic wastes	Contractor landfill	200
Solid organic wastes and trash	Contractor landfill	200
Fluid residues	Incineration, uncontrolled, energy recovery	14,100
Fluid residues, miscellaneous		1,600
Sludge, filter residues	Landfill	360
Solid reactor residues	Landfill	160

Table C-8. (Continued)

Individual Hazardous Waste Stream	Disposal Process	Actual Quantity, metric tons/yr
Solid residual pitch	Landfill	830
Solid, spent metal oxide catalyst	Recovery and byproduct sales	60
Fluid, reactor residue	Incineration, uncontrolled, energy recovery	170
Fluid, reactor recycle		60
Fluid, still heads		130
Solid, spent metal catalyst	Recovery and recycle	14
Liquid (thick), reactor residue	Incineration, uncontrolled, energy recovery	680
Semi-solid residue	Landfill	16
Liquid, wash water waste	Activated sludge and lagoon[5]	1,000
Liquid, activated sludge from wash water waste	Incineration, controlled	90
Liquid, activated sludge, tar	Incinerator, controlled	4
Liquid, activated sludge	Incineration, controlled	36
Solids, filter residues	Incineration, controlled	70
Liquid reaction waste	Deep well injection	22,700
Liquid purification waste	Deep well injection	11
Liquid activated sludge from water-phase wastes	Incineration, controlled	5
Liquid still bottoms	Incineration, controlled	800
Liquid still bottoms	Incineration, controlled	800
Liquid, contaminated steam condensate	Deep well injection	90
Liquid, contaminated wash water	Deep well injection	30
Liquid, activated sludge from aqueous chloroaromatic wastes	Incineration, controlled	20
Liquid, activated sludge from aqueous chloroaromatic wastes	Incineration, controlled	80

Table C-8. (Continued)

Individual Hazardous Waste Stream	Disposal Process	Actual Quantity, metric tons/yr
Liquid still heavy ends	Incineration, controlled	500
Liquid, phenolic contaminated wash water	Activated sludge and lagoon	90
Liquid, activated sludge from wash water waste	Incineration, controlled	3
Liquid still bottoms	Incineration, controlled	70
Liquid, reprocessing tars	Incineration, controlled	200
Liquid, neutralization products	Deep well injection	6,000
Liquid, scrubber waste	Incineration, controlled (salt ash to industrial outfall)	400
Semi-solid, filter cake	Landfill	280
Liquid, still bottoms	Incineration, controlled (salt ash to industrial outfall)	1,100
Liquid, wash water	Activated sludge and lagoon	600
Liquid, activated sludge from wash water waste	Incineration, controlled	100
Liquid, contaminated condensate	Activated sludge and lagoon	20
Liquid, activated sludge from contaminated condensate	Incineration, controlled	4
Semi-solid, filter cake	Landfill	500
Liquid, wash-down wastes	Activated sludge and lagoon	100
Liquid, activated sludge from wash-down wastes	Incineration, controlled	20
Solid, spent ion exchange resin	Landfill	1
Solid, spent charcoal	Thermal regeneration (recovery)	50
Solid, wastes/residues	Incineration, uncontrolled	Not Available

Table C-8. (Continued)

Individual Hazardous Waste Stream	Disposal Process	Actual Quantity, metric tons/yr
Liquid, activated sludge from wastewater	Evaporation (spread on farm land)	Not Available
Liquid, neutralized Al salt solution	Contractor deep well, landfill and incineration	Not Available
Liquid wastes, toxic	Contractor disposal	Not Available
Liquid, oil sludge from waste water	Contractor disposal	Not Available
Solid, catalyst residue, Ni compounds	Recovery (Ni — 100%)	3
Solid, catalyst residue, Cr compounds	Recovery (Cr — 100%)	<1
Solid, catalyst residue, SiC compounds	Recovery	20
Liquid, distillation residue	Incineration, uncontrolled energy recovery	2,700
Solid, catalyst residue, Ni compounds	Recovery (Ni — 100%)	3
Solid, catalyst residue, Cr compounds	Recovery (Cr — 100%)	<1
Solid, catalyst residue, SiC compounds	Recovery	20
Fluid, aromatic residues	Incineration, uncontrolled energy recovery	260
Solid, spent catalyst, Sb salt	Landfill (encapsulated)	20
Solid, spent catalyst, Cu and oxides	Recovery (Cu — 100%)	3
Solid, spent catalyst (mol-sieve)	Landfill	5
Liquid, viscous	Incineration, uncontrolled energy recovery	8,200
Solid, spent catalyst, Ni compounds	Recovery (Ni — 100%)	20
Solid, spent catalyst, Cr compounds	Recovery (Cr — 100%)	<1

Table C-8. (Continued)

Individual Hazardous Waste Stream	Disposal Process	Actual quantity, metric tons/yr
Solid, spent catalyst, SiC compounds	Recovery	20
Solid, spent catalyst, Co compounds	Incineration, uncontrolled, energy recovery	3
Solid, waste Na metal	Landfill	1
Fluid, organic residue	Incineration, uncontrolled energy recovery	300
Fluid, organic cyclic gums		9,000
Liquid, dryer waste, Ca salts	Deep well injection	14
Liquid, dryer waste, Ca salts	Deep well injection	5
Liquid, activated sludge	Incineration, controlled	230
Solid, filter wastes	Incinerator[6]	4
Liquid, vent scrubber wastes	Activated sludge and lagoon[7]	6,500
Liquid, tar dump	Activated sludge and lagoon[7]	45
Liquid, organics/acid	Activated sludge and lagoon[7]	2,300
Liquid, residues	Activated sludge and lagoon[7]	90
Semi-solid, chlorinated hydrocarbon heavies	Deep well injection	13,600
Semi-solid, lead compound sludge	Recovery furnace	9,100
Fluid, reactor byproduct	Incineration, controlled, energy recovery	1,600
Solid, copper compound residues	Recovery	3
Solid, Cr compound residues	Recovery	1

Table C-8. (Continued)

Composite Hazardous Waste Streams[8]		Disposal Process	Actual Quantity, metric tons/yr
4	Liquid hazardous waste streams	Recovery	2,350
5	Liquid hazardous waste streams	Incineration, controlled	3,860
10	Liquid hazardous waste streams	Incineration, uncontrolled	10,000
14	Liquid hazardous waste streams	Landfill	1,100[9]
23	Solid hazardous waste streams	Landfill	5,800[9]
4	Liquid or solid hazardous waste streams	Lagooned	Not Available
5	Liquid or solid hazardous waste streams	Contractor incineration	2,100
5	Liquid or solid hazardous waste streams	Contractor landfill	4,700

1. 90% organics.
2. Metal recovered from incinerator ash.
3. About 0.5% organics in water.
4. Highly dangerous compound — 700 metric tons/year. Moderately dangerous compound — 600 metric tons/year.
5. Salts to outfall.
6. Soluble salts to industrial outfall, silicates to landfill.
7. Salts to industrial outfall.
8. Data composited to protect proprietary information.
9. Includes 800 metric tons stored hazardous wastes.

[a] This table provides the reader with general information on common disposal methods for various types of wastes, based on a survey of organic chemical plants.

Source: TRW 1975.

APPENDIX D

INFORMATION IN SUPPORT OF STAGE III

Exhibit D-1. The Hazardous Waste Data Management System (HWDMS)

The Hazardous Waste Data Management System (HWDMS) maintained by the EPA State Programs and Resource Recovery Division of the EPA Office of Solid Waste (OSW) provides a computerized means of tracking permit applications for the treatment/storage/disposal (TSD) of hazardous waste. The system can be accessed by SIC code to obtain the names and locations of all facilities within an industry group that have applied for permission to treat, store, or dispose of any hazardous wastes. A complete printout of permit application data is available at the EPA Office of Solid Waste, arranged by zip code. This must be consulted manually. For each location, the printout provides the type of hazardous waste facility (i.e., landfill, incinerator, etc.) and its proposed capacity. See Table D-4 in Appendix D for a list of the TSD process codes and capacity units in the data base. The system can also identify waste stream types and volumes handled by each on-site disposal practice, but these data are considered unreliable by OSW staff and thus are useless at the present time. Both on- and off-site facilities are listed and in the near future, HWDMS will incorporate a "tag" that distinguishes between on- and off-site facilities. A recent summary compilation of hazardous waste sites included in the HWDMS data base is provided as Table D-7 in Appendix D.

The HWDMS is most useful in Stages III and IV. For Stage III, it can determine what kind on on-site facilities are available in the geographic area of interest in order to confirm or correct data obtained from other sources. This can be accomplished by requesting a printout of the names and locations of all hazardous waste TSD facilities in the study area. More detailed information on these facilities can then be obtained by examining the printout of permit application data (by EPA Region) available at OSW. For Stage IV, the system will supply actual locations; commercial (off-site) waste handlers may be located by using the commercial "tag"; it is not known at this time whether these facilities can be extracted using the waste disposal SIC code (4953). Plants lacking on-site facilities may be assumed to dispose of hazardous waste at the nearest off-site facility possessing the requisite treatment type in the absence of better information.

Note the following caveats:

- The EPA staff has not had the time to verify the application data before entering it in the HWDMS. SIC codes and TSD information may not accurately reflect the actual plans of the facility. As EPA reviews applications, however, appropriate corrections will be made in the applications and the data base.

- Because the application information is submitted in advance of operations, the proposed facilities and types of wastes treated may not be representative of the current conditions. For example, a proposed incinerator may not be built, and the list of wastes handled includes all wastes that might be treated.

- Many unnecessary and misleading entries are included in the data base. For example, gas station owners in some areas thought that they had to apply for a TSD permit, and many corporate headquarters mistakenly applied for a TSD permit, even though no hazardous waste is handled on-site. Therefore, any retrieval should be examined carefully and discussed with OSW Staff.

Table D-1. POTWs: Treatment Populations - Present and Projected, Resident and Nonresident (in Thousands)[a]

State	1980 Ceiling population[b]	Receiving treatment[c]		Not receiving treatment[c]		Percent served[f]
		1980 Res.[d]	1980 Nonres.[e]	1980 Res.[d]	1980 Nonres.[e]	1980
Alabama	3,769	2,002	103	533	4	53.1
Alaska	406	201	3	121	3	49.7
Arizona	2,450	1,802	66	374	14	73.6
Arkansas	2,180	1,215	23	220	0	55.7
California	22,696	19,451	1,042	1,421	43	85.7
Colorado	2,772	2,445	165	34	0	88.6
Connecticut	3,115	1,885	30	1,176	0	60.5
Delaware	582	463	80	79	31	79.7
Dist. of Colum.	656	729	1,898	0	0	111.2
Florida	8,880	4,717	819	2,236	57	53.2
Georgia	5,118	3,037	135	753	4	59.4
Hawaii	915	585	90	212	9	64.0
Idaho	905	480	13	99	23	53.1
Illinois	11,230	9,940	32	285	0	88.5
Indiana	5,400	3,475	242	412	54	64.3
Iowa	2,903	2,095	69	148	28	72.2
Kansas	2,369	1,822	13	171	1	76.9
Kentucky	3,527	1,680	60	760	0	47.6
Louisiana	4,026	2,815	68	448	6	69.9
Maine	1,097	485	82	431	7	44.3
Maryland	4,149	2,441	127	507	127	58.8
Massachusetts	5,769	3,745	50	1,793	82	64.9
Michigan	9,208	6,778	123	1,428	36	73.6
Minnesota	4,060	2,980	23	208	6	71.6
Mississippi	2,406	1,449	15	485	1	60.3
Missouri	4,868	3,432	878	297	5	70.5
Montana	786	482	32	32	1	61.3
Nebraska	1,574	1,351	17	57	0	85.8
Nevada	702	605	90	46	0	86.3
New Hampshire	887	362	57	417	60	40.8
New Jersey	7,332	5,760	804	1,167	141	78.6
New Mexico	1,241	1,034	16	122	6	83.4
New York	17,649	12,457	2,388	5,309	405	70.6

Table D-1. (Continued)

State	1980 Ceiling population[b]	Receiving treatment[c] 1980 Res.[d]	 1980 Nonres.[e]	Not receiving treatment[c] 1980 Res.[d]	 1980 Nonres.[e]	Percent served[f] 1980
North Carolina	5,606	2,373	179	1,415	103	42.5
North Dakota	657	434	0	7	0	66.2
Ohio	10,731	8,297	66	985	3	77.3
Oklahoma	2,892	2,135	2	183	7	73.8
Oregon	2,527	1,443	39	338	3	57.1
Pennsylvania	11,731	8,735	528	2,538	232	74.5
Rhode Island	929	589	48	304	0	63.4
South Carolina	2,932	1,291	233	639	51	44.1
South Dakota	689	454	13	17	0	65.9
Tennessee	4,380	2,163	68	930	1	49.4
Texas	13,385	11,042	311	1,045	38	82.5
Utah	1,367	1,166	15	87	6	85.3
Vermont	493	225	46	126	16	45.7
Virginia	5,197	3,315	297	1,135	6	63.8
Washington	3,926	2,360	437	582	28	60.1
West Virginia	1,878	761	16	1,053	3	40.6
Wisconsin	4,720	3,479	72	338	21	73.7
Wyoming	450	328	16	2	1	72.9
American Samoa	31	1	0	30	0	4.5
Guam	114	72	3	18	0	63.9
N. Marianas	17	1	0	17	0	8.1
Puerto Rico	3,358	1,757	0	1,184	0	52.3
Pac. Tr. Terr.	111	22	0	95	0	20.6
Virgin Islands	96	66	3	20	0	68.8
U.S. TOTALS	223,824	156,673	12,070	34,898	1,698	70.0

Table D-1. Footnotes

[a] Table D-1 summarizes the populations by state which are now or will be receiving treatment of their wastewaters.

[b] The values listed for the 1980 state ceiling populations were obtained from data provided by the Department of Commerce, Bureau of Economic Analysis (BEA). The 1980 total is the BEA estimate of the number of current state residents.

[c] Persons are included in the Receiving Treatment category if the wastewater they generate is treated at a facility operated by an established sewerage authority. Persons are included in the Not Receiving Treatment category if they reside in the service area of an established sewerage authority but the wastewater they generate is not treated at a facility operated by the authority. Theoretically the sum of the populations receiving treatment and not receiving treatment should equal the state's total population. This is not the case because many rural residents who are counted as part of the state's total do not reside in the service area of any established sewerage authority and, therefore, are not included in any Receiving or Not Receiving Treatment categories. All levels of treatment are included under Receiving Treatment. Similar summaries are presented in other tables of USEPA 1981e that provide information for each specific level of treatment.

[d] Resident populations (Res) are permanent residents within the service ara of an established sewerage authority.

[e] Nonresident populations (Nonres) include commuters living in one service area and working in another, as well as temporary residents at resort areas and similar locations.

[f] The Percent Served values are based upon a comparison between the resident population receiving treatment and the total state population figures provided by BEA.

Source: USEPA 1981e.

Table D-2. POTWs: Average Domestic Flows by State - Present, Projected, and Percent Change (Thousands of Cubic Meters per Day)[a]

State	Actual[b]			Present design[c]		
	Total flow[d]	Domestic flow[e]	Liters/capita/ day[f]	Total flow[d]	Domestic flow[e]	Liters/capita/ day[f]
Alabama	1,262	1,032	490	1,726	1,486	705
Alaska	135	121	595	220	201	990
Arizona	755	728	389	1,043	994	531
Arkansas	631	512	413	1,015	900	726
California	8,739	7,233	361	11,909	9,825	490
Colorado	1,168	974	371	1,619	1,389	530
Connecticut	1,358	1,123	588	2,067	1,625	852
Delaware	317	176	324	425	281	517
Dist. of Colum.	1,128	1,128	429	1,169	1,169	445
Florida	2,343	2,137	386	4,053	3,775	682
Georgia	1,933	1,489	469	3,140	2,524	795
Hawaii	363	325	480	547	513	759
Idaho	343	281	570	541	457	925
Illinois	7,745	6,235	625	9,655	7,777	780
Indiana	2,723	2,152	582	3,853	3,048	824
Iowa	1,161	963	444	1,447	1,205	556
Kansas	844	720	392	1,228	1,035	563
Kentucky	990	755	433	1,307	980	563
Louisiana	1,304	1,263	438	1,914	1,861	645
Maine	418	323	570	525	412	725
Maryland	1,347	1,136	442	2,007	1,794	698
Massachusetts	3,235	2,475	652	3,942	2,969	782
Michigan	5,332	4,176	607	6,782	6,068	882
Minnesota	1,586	1,121	382	2,052	1,523	519
Mississippi	952	834	576	1,139	1,049	725
Missouri	2,199	1,798	417	3,430	2,706	627
Montana	246	239	464	399	390	758
Nebraska	658	513	375	987	818	597
Nevada	576	575	827	709	709	1,018
New Hampshire	284	207	494	509	401	956
New Jersey	3,959	3,124	477	4,793	4,310	659
New Mexico	388	364	346	524	500	476

Table D-2. (Continued)

State	Actual[b]			Present design[c]		
	Total flow[d]	Domestic flow[e]	Liters/capita/day[f]	Total flow[d]	Domestic flow[e]	Liters/capita/day[f]
New York	9,396	8,508	573	11,473	10,282	692
North Carolina	1,681	1,077	422	2,570	1,832	718
North Dakota	149	136	314	156	143	328
Ohio	5,439	4,398	527	7,104	5,686	682
Oklahoma	927	847	396	1,308	1,214	566
Oregon	1,052	807	549	1,646	1,340	912
Pennsylvania	5,368	4,600	496	6,531	5,641	609
Rhode Island	458	302	474	640	450	719
South Carolina	945	686	449	1,400	1,092	716
South Dakota	209	180	386	268	238	509
Tennessee	1,709	1,226	550	2,559	1,907	856
Texas	5,596	5,080	447	7,186	8,610	582
Utah	808	743	629	1,024	912	772
Vermont	168	150	552	217	200	738
Virginia	1,635	1,466	405	2,458	2,029	561
Washington	1,604	1,401	500	2,212	1,960	701
West Virginia	387	326	422	611	541	700
Wisconsin	2,406	1,806	508	3,461	2,487	700
Wyoming	172	171	496	170	169	492
American Samoa	1	1	967	4	4	2,481
Guam	24	24	326	98	98	1,294
N. Marianas	2	2	1,452	4	4	2,660
Puerto Rico	517	468	266	412	363	206
Pac. Tr. Terr.	1	1	54	12	12	525
Virgin Islands	14	14	214	32	32	463
U.S. TOTALS	97,117	80,679	479	130,260	109,981	654

Table D-2. Footnotes

[a] Table D-2 summarizes the present (1980) quantity of flow treated by publicly owned treatment plants that is from domestic sources. A similar summary dealing with flow from industrial souces is presented elsewhere in USEPA 1981e. Flows in cubic meters x 1000. Sum of entries may not equal total due to round-offs.

[b] Actual: All flows reported in this category are compiled from the Actual Average Daily Flow received at treatment works during the most recent 12 month period for which information is available. Flows reported in this category were compiled from records collected between late 1978 and early 1980. The major source of flow information was the self-monitoring reports that are completed by every facility with an NPDES permit.

[c] Present Design: All flows reported in this category are compiled from the average daily flow a treatment plant is designed to handle. The design capacity reported was capacity in place in 1980.

[d] Total Flow: The total flow is expressed in thousands of cubic meters per day. Total flow is defined as all wastewaters moving through the treatment plant from all sources, including domestic, commercial, industrial, and infiltration/inflow.

[e] Domestic Flow: The domestic flow is expressed in thousands of cubic meters per day. Domestic flow is defined as all waste waters moving through the treatment plant from all sources except industrial sources.

[f] Liters/Capita/Day: These values are calculated using the Domestic Flow and the total resident and nonresident population. The actual number of residents and nonresidents receiving treatment in 1980 was used in the Actual and Present Design. Flows in cubic meters x 1000. Sum of entries may not equal total due to round-offs.

Source: USEPA 1981e.

Table D-3. State Solid Waste Agencies
U.S. Environmental Protection Agency
Office of Solid Waste

Alabama
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Table D-4. Hazardous Waste Treatment, Storage, and Disposal Process Codes Used in HWDMS

Process	Process Code	Appropriate units of measure for process design capacity
Storage:		
Container (barrel, drum, etc.)	S01	Gallons or liters
Tank	S02	Gallons or liters
Waste file	S03	Cubic yards or cubic meters
Surface impoundment	S04	Gallons or liters
Disposal:		
Injection well	D79	Gallons or liters
Landfill	D80	Acre-feet (the volume that would cover one acre to a depth of one foot) or hectare-meter
Land application	D81	Acres or hectares
Ocean disposal	D82	Gallons per day or liters per day
Surface impoundment	D83	Gallons or liters
Treatment:		
Tank	T01	Gallons per day or liters per day
Surface impoundment	T02	Gallons per day or liters per day
Incinerator	T03	Tons per hour or metric tons per hour; gallons per hour or liters per hour
Other (Use for physical, chemical, thermal or biological treatment processes not occurring in tanks, surface impoundments or incinerators.)	T04	Gallons per day or liters per day

Table D-4. (continued)

Unit of measure	Unit of measure code
Gallons	G
Liters	L
Cubic yards	Y
Cubic meters	C
Gallons per day	U
Liters per day	V
Tons per hour	D
Metric tons per hour	W
Gallons per hour	E
Liters per hour	H
Acre-feet	A
Hectare-meter	F
Acres	B
Hectares	Q

Source: EPA Form 3510-3.

Table D-5. Information on Hazardous Wastes Listed by RCRA in the Federal Register on May 19, 1980 (See Footnotes for explanation of symbols used)

	Ident. Codes		Characteristics				Management Methods		
								Incineration	
Hazardous Waste	EPA No. (Part 261)	Sic Code	Hazard Code	Physical State	Hazardous Constituents	Geographic Distribution	Present Practices	Potential	Type
Bottom sediment sludge from the treatment of wastewaters from wood preserving processes that use creosote and/or pentachlorophenol	K001	2491	T	Solid	Benzene, benz(a) anthracene, benzo (a)pyrene, chrysene 4-nitrophenol, toluene, napthalene phenol, 2-chlorophenol, 2,4-dimethyl phenol, 2,4,6-trichlorophenol, pentachlorophenol, 4,6-dinitro-o-cresol, tetrachlorophenol	Widespread	landfilled	G	RK;FBC
Inorganic Pigments:									
Wastewater treatment sludge from the production of chrome yellow and orange pigments	K002	2816	T	Sludge	Hexavalent Chromium lead	60% of chrome pigments and iron blue pigments are manufactured by two plants in N.E. U.S.; rest is manufactured in the midwest and south	on-site ponding; on-site and off-site landfilling; land dumping; discharge to sewer; frequently mixed for disposal	P	NA
Wastewater treatment sludge from the production of molybdate orange pigments	K003	2816	T	Sludge	Hexavalent Chromium lead	60% of chrome pigments and iron blue pigments are manufactured by two plants in N.E. U.S.; rest is manufactured in the midwest and south	on-site ponding; on-site and off-site landfilling; land dumping; discharge to sewer; frequently mixed for disposal	P	NA
Wastewater treatment sludge from the production of zinc yellow pigments	K004	2816	T	Sludge	Hexavalent Chromium lead	60% of chrome pigments and iron blue pigments are manufactured by two plants in N.E. U.S.; rest is manufactured in the midwest and south	on-site ponding; on-site and off-site landfilling; land dumping; discharge to sewer; frequently mixed for disposal	P	NA
Wastewater treatment sludge from the production of chrome green pigments	K005	2816	T	Sludge	Hexavalent Chromium	60% of chrome pigments and iron blue pigments are manufactured by two plants in N.E. U.S.; rest is manufactured in the midwest and south	on-site ponding; on-site and off-site landfilling; land dumping; discharge to sewer; frequently mixed for disposal	P	NA
Wastewater treatment sludge from the production of chrome oxide green pigments	K006	2816	T	Sludge	Hexavalent Chromium	60% of chrome pigments and iron blue pigments are manufactured by two plants in N.E. U.S.; rest is manufactured in the midwest and south	on-site ponding; on-site and off-site landfilling; land dumping; discharge to sewer; frequently mixed for disposal	P	NA
Wastewater treatment sludge from the production of iron blue pigments	K007	2816	T	Sludge	Hexavalent Cyanide (complexed) chromium	60% of chrome pigments and iron blue pigments are manufactured by two plants in N.E. U.S.; rest is manufactured in the midwest and south	on-site ponding; on-site and off-site landfilling; land dumping; discharge to sewer; frequently mixed for disposal	P	NA

Table D-5. (Continued)

Hazardous Waste	Ident. Codes		Characteristics				Management Methods		
	EPA No. (Part 261)	Sic Code	Hazard Code	Physical State	Hazardous Constituents	Geographic Distribution	Present Practices	Incineration	
								Potential	Type
Oven residue from the production of chrome oxide green pigments	K008	2816	T	Solid	Hexavalent Chromium	60% of chrome pigments and iron blue pigments are manufactured by two plants in N.E. U.S.; rest is manufactured in the midwest and south	on-site ponding; on-site and off-site landfilling; land dumping; discharge to sewer; frequently mixed for disposal	P	NA
Organic Chemicals:									
Distillation bottoms from production of acetaldehyde from ethylene	K009	2869	T	Aqueous liquid	Chloroform, formaldehyde, methylene chloride, methyl chloride, paraldehyde, formic acid	Bay City, Clare Lake	Deepwell injection; Anerobic lagoons	P	LI,RK
Distillation side cuts from production of acetaldehyde from ethylene	K010		T	Organic liquid	Chloroform, formaldehyde, methylene chloride, methyl chloride, paraldehyde, formic acid, chloroacetaldehyde	Bay City, Clare Lake and Longview, TX	Deepwell injection	C	LI;RK;R FBC
Bottom stream from wastewater stripper in acrylonitrile production	K011	2869	R,T	Aqueous liquid	Acrylonitrile, acetonitrile, hydrocyanic acid	New Orleans; Beaumont, Chocolate Bayou, Texas City, TX, Memphis; Lima, OH	Settling ponds; deepwell injection, municipal sewer; Badger modification allow incineration of all streams. (Wastes are often mixed)	P	NA
Bottom stream from acetonitrile column in the production of acrylonitrile	K013	2869	R,T	Aqueous liquid (wash water)	Hydrocyanic acid, acrylonitrile, acetonitrile	New Orleans; Beaumont, Chocolate Bayou, Texas City City, TX, Memphis; Lima OH	Settling pond; deep well injection in municipal sewer; Requires concentration before incineration (Wastes are often mixed)	C	LI;RK; FBC
Bottoms from acetonitrile purification column in the production of acrylonitrile	K014	2869	T	Organic liquid	Acetonitrile, acrylamide	New Orleans; Beaumont, Chocolate Bayou, Texas City, TX; Memphis, Lima, OH	Settling pond; deepwell injection; municipal sewer (Wastes are often mixed)	C	LI;RK:
Still bottoms from distillation of benzyl chloride	K015	2865	T	Organic sludge	Benzyl chloride, chlorobenzene, toluene, benzotrichloride		Incineration, landfilling	P	LI;RK; FBC
Distillation residues from production of carbon tetrachloride (Heavy ends)	K016	2869	T	Organic	Hexachlorobenzene, hexachlorobutadiene, carbon tetrachloride, hexachloroethane, perchloroethylene	Moundsville, S. Charleston W.VA; Freeport and Corpus Christi, TX; Plaquemine and Geisman, LA; Pittsburg, Califronia, Le Moyne, AL, Louisville, KY; Wichita, KS	Drums in landfills; incineration	P	RK;FBC

Table D-5. (Continued)

Hazardous Waste	Ident. Codes		Characteristics				Management Methods		
	EPA No. (Part 261)	SIC Code	Hazard Code	Physical State	Hazardous Constituents	Geographic Distribution	Present Practices	Incineration Potential	Incineration Type
Still bottoms from epichlorohydrin purification column	K017	2869	T	Organic liquid	Epichlorohydrin, chloroethers (bis-(chloromethyl) ether and bis (2-chloroethyl) ethers), trichloropropane, dichloropropanols	Freeport and Deer Park, TX Norco, LA	Holding ponds prior to incineration	P	RK;FBC
Heavy ends from fractionation in ethyl chloride production	K018	2869	T	Organic liquid	1,2-dichloroethane, trichloroethylene, hexachlorobutadiene hexachlorobenzene	Houston and Freeport, TX; Lake Charles and Baton Rouge, LA; Deepwater, NJ; Long Beach, CA	Land disposal; some incineration	P	RK;FBC
Heavy ends from distillation of ethylene dichloride in ethylene dichloride production	K019	2869	T	Organic liquid	ethylene dichloride, 1,1,1-trichloroethane, 1,1,2-trichloroethane, tetrachloroethanes (1,1,2,2-tetrachloroethane and 1,1,1,2-tetrachloroethane), trichloroethylene, tetrachloroethylene, carbon tetrachloride, chloroform, vinyl chloride, vinylidene chloride	20 Plants - most in LA and TX	Not known	P	RK;FBC
Heavy ends from distillation of vinyl chloride in production of VCM	K020	2869	T	Organic	ethylene dichloride, 1,1,1-trichloroethane, 1,1,2-trichloroethane, tetrachloroethanes (1,1,2,2-tetrachloroethane), trichloroethylene, tetrachloroethylene, carbon tetrachloride, chloroform, vinyl chloride, vinylidene chloride	Mainly in Texas and Louisiana	Incineration, landfilling	P	RK,FBC
Aqueous spent antimony catalyst waste from fluoromethanes produc-	K021		T	Aqueous sludge	antimony, carbon tetrachloride, chloroform	Baton Rouge and Gramercy, LA; Elizabth and Deepwater NJ; Danville IL, El Segundo and Antioch, CA; Louisville and Calvert, KY; Corpus Christi, TX; Wichita, KS	Claylined pits	P	NA
Distillation bottom tars from production of phenol/acetone from cumene	K022	2869	T	Organic sludge (tarry solid)	phenol, tars (polycyclic aromatic hydrocarbons)	Widespread distribution	Landfilling, incineration	G	RK;FBC

Table D-5. (Continued)

Hazardous Waste	Ident. Codes		Characteristics				Management Methods		
	EPA No. (Part 261)	Sic Code	Hazard Code	Physical State	Hazardous Constituents	Geographic Distribution	Present Practices	Incineration	
								Potential	Type
Distillation light ends from production of phthalic anhydride from naphthalene	K023	2869	T	Liquid	Phthalic anhydride Maleic anhydride	Richmond & El Sequendo, CA; Kearney & Bridgeport, NJ; Baton Rouge, LA: Bridgeville & Neville Island, PA; Cicero & Milledale, IL; Texas City, TX	Incinerated; off-site disposal	G	LI;RK; FBC
Distillation bottoms from production of phthalic anhydride from naphthalene	K024	2869	T	Organic sludge	Phthalic anhydride Naphthaquinone Polynuclear tarlike materials	Richmond & El Sequendo, CA; Kearney & Bridgeport, NJ; Baton Rouge, LA· Bridgeville & Neville Island, PA; Cicero & Milledale, IL; Texas City, TX	Landfilled; incineration	G	LI;RK; FBC
Distillation bottoms from production of nitrobenzene by nitration of benzene	K025	2865	T	Organic sludge	Dinitrobenzene Dinitrotoluene	Bound Brook, NJ; Pee Willow Island, W.VA Beaumont, TX Gibbstown, NJ Geismar, LA New Martinville, W.VA	Often mixed for disposal in landfill	G	LI,RK, FBC
Stripping still tails from production of methyl ethyl pyridines	K026	2869	T	Aqueous	Paraldehyde, pyridines, picolines	Koppers Company, Inc. Nepera Chemical Co., Inc. Reilly Tar and Chemical NIT-Chem Co., Inc.	Goes to water treatment lagoons, sludge to land disposal	G	RK;FBC
Centrifuge residue from toluene diisocyanate production	K027	2869	R,T	Organic sludge	Toluene diisocyanate, toluene, diamine, tars	Moundsville & New Martinville, W.VA.; Geismar & Lake Charles, LA; Freeport & Baytown, TX; Ashtabula, OH	Landfilled; drums in landfills	G	RK;FBC
Spent Catalyst from hydrochlorinator reactor in production of 1,1,1-trichloroethane	K028	2869	T	Sludge	Trichloroethane, Vinyl chloride	Freeport, TX; Lake Charles, Plaquemine & Geisman, LA	Landfilled (some in drums) some incineration	P	NA
Waste from 1,1,1-trichloroethane steam stripper	K029	2869	T	Aqueous liquid	Dichloroethane, trichloroethane, vinyl chloride, vinylidene chloride chloroform	Freeport TX; Lake Charles, Plaquemine & Geismen, LA	Pits, landfills	P	RK;FBC
Column bottoms from trichloroethylene and perchloroethylene production	K030	2869	T	Organic liquid	Hexachlorobenzene, hexachlorobutadiene hexachloroethane, tetrachloroethane, ethylene dichloride	Freeport, Deer Park & Corpus Christi, TX: Baton Rouge Lake Charles, Plaquemine, LA; Pittsburg, CA; Louisville, KY; Wichita, KS	Incineration, landfilled	P	RK;FBC

Table D-5. (Continued)

Hazardous Waste	Ident. Codes		Characteristics				Management Methods		
	EPA No. (Part 261)	Sic Code	Hazard Code	Physical State	Hazardous Constituents	Geographic Distribution	Present Practices	Incineration	
								Potential	Type
Pesticides:									
By-products salts generated in the production of MSMA and cacodylic acid	K031	2869	T	Solid waste - saltcake	arsenic	Green Bayou, Houston, TX, Vineland, NJ	Previously landfilled deepwell injection Often mixed for disposal	P	NA
Wastewater treatment sludge from the production of chlordane	K032	2879	T	Sludge	hexachlorocyclopentadiene	Marshall, IL	Landfilled	P	RK;FBC
Wastewater and scrubwater from the chlorination of cyclopentadiene in the production of chlordane	K033	2879	T	Aqueous liquid	hexachlorocyclopentadiene	Marshall, IL	Holding pond then filtered prior to deepwell injection	P	NA
Filter solids from the filtration of hexachlorocyclopentadiene	K034	2869	T	Solid	hexachlorocyclopentadiene	Marshall, IL	Landfilled	P	RK;FBC
Wastewater treatment sludges generated in the production of creosote	K035	2861	T	Sludge	creosote, benz(a)-anthracene, benz(b)-fluoroanthene, benzo(a)pyrene	Widespread distribution	Landfilled	P	RK;FBC
Still bottoms from toluene reclamation distillation in the production of disulfoton	K036	2879	T	Sludge	toulene, phosphorodithioic and phosphorothioic acid esters	Kansas City, MO	Landfilled; often mixed for disposal	P	RK;FBC
Wastewater treatment sludges from the production of disulfoton	K037	2879	T	Aqueous liquid	toulene, phosphorodithioic and phosphorothioic acid esters	Kansas City, MO	Landfilled	P	RK;FBC
Wastewater from the washing and stripping of phorate production	K038	2879	T	Aqueous liquid	phorate, formaldehyde, phosphorodithioic and phosphorothioic acid esters	Hannibal, MO Kansas City, MO	Lagoons, holding ponds, land treatment	P	NA
Filter cake from the filtration of diethylphosphorodithoric acid in the production of phorate	K039	2879	T	Solid	phosphorodithioic and phosphorothioic acid esters	Hannibal, MO; Kansas City, MO	Lagoons, holding ponds, land treatment, some incineration	P	RK;FBC
Wastewater treatment sludge from the production of phorate	K040	2879	T	Sludge	phorate, formaldehyde, phosphorodithioic and phosphorothioic acid esters	Hannibal, MO; Kansas City, MO	Lagoons. holding ponds, land treatment. some incineration	P	RK;FBC
Wastewater treatment sludge from the production of toxaphene	K041	2879	T	Sludge	toxaphene	Brunswick, GA: Vicksburg, MS	Holding ponds, dried to 50% solids, landfilled	P	RK;FBC

Table D-5. (Continued)

Hazardous Waste	Ident. Codes		Characteristics				Management Methods		
	EPA No. (Part 261)	Sic Code	Hazard Code	Physical State	Hazardous Constituents	Geographic Distribution	Present Practices	Incineration Potential	Incineration Type
Heavy ends or distillation residues from the distillation of tetrachlorobenzene in the production of 2, 4,5-T	K042	2879	T	Organic Solid	hexachlorobenzene; ortho-dichlorobenzene		Landfilled; surface placement	F	RK;FBC
2,6-Dichlorophenol waste from the production of 2,4-D	K043	2879	T	Sludge	2,4-dichlorophenol, 2,6-dichlorophenol, 2,4,6-trichlorophenol	Jacksonville, AK Dow Chemical	Landfills (Chemical)	F	RK;FBC
Explosives:									
Wastewater treatment sludges from the manufacturing and processing of explosives	K044	2892	R	Sludge	NA	30 states (104 facilities) CA, Utah, MD, PA, have the greatest number of facilities. TN, WS, VA, IL have greatest number of GOCO plants	Open burning, percolation/evaporation ponds, detonation of dry sumps	F	RK;FBC
Spent carbon from the treatment of wastewater containing explosives	K045	2892	R	Solid	NA	30 states (104 facilities) CA, Utah, MD, PA, have the greatest number of facilities. TN, WS, VA, IL have greatest number of GOCO plants	Open burning, percolation/evaporation ponds, detonation of dry sumps	G	RK;FBC
Wastewater treatment sludges from the manufacturing, formulation and loading of lead-based initiating compounds	K046	2892	T	Sludge	Lead	30 states (104 facilities) CA, Utah, MD, PA, have the greatest number of facilities. TN, WS, VA, IL have greatest number of GOCO plants	Landfill	P	NA
Pink/red water from TNT operations	K047	2892	R	Aqueous liquid	NA	30 states (104 facilities) CA, Utah, MD, PA, have the greatest number of facilities. TN, WS, VA, IL have greatest number of GOCO plants	Evaporation ponds	G	TP
Petroleum Refining:									
Dissolved air flotation (DAF) float from the petroleum refining industry	K048	2911	T	Sludge	chromium, lead	Widespread distribution	On-site land treatment and incineration; on-site and off-site lagoon and Landfill	G	RK;FBC
Slop oil emission solids from the petroleum refining industry	K049	2911	T	Sludge	chromium, lead	Widespread Distribution	on-site land treatment and incineration; on-site and off-site lagoon and landfill	G	RK;FBC
Heat exchanger bundle cleaning sludge from the petroleum refining industry	K050	2911	T	Sludge	chromium	Widespread Distribution	on-site land treatment and incineration: on-site and off-site lagoon and landfill	F	RK;FBC

Table D-5. (Continued)

Hazardous Waste	Ident. Codes		Characteristics				Management Methods		
	EPA No. (Part 261)	Sic Code	Hazard Code	Physical State	Hazardous Constituents	Geographic Distribution	Present Practices	Incineration	
								Potential	Type
API separator sludge from the petroleum refining industry	K051	2911	T	Sludge	chromium, lead	Widespread Distribution	on-site land treatment	G	RK;FBC
Tank bottoms (leaded) from the petroleum refining industry	K052	2911	T	Sludge	lead	Widespread Distribution	on-site land treatment and incineration: on-site and off-site lagoon and landfill	F	RK;FBC
Iron and Steel Industry:									
Ammonia still lime sludge from coking operations	K060	3312	T	Sludge	cyanide, naphthalene, phenolic compounds, arsenic	17 different states with approx. 50% located in Pennsylvania, Ohio, Alabama	Approx. 75% of the plants are on-site unlined sludge ponds	P	NA
Emission control dust/sludge from the electric furnace production of steel	K061	3312	T	Solids or sludge	chromium, lead, cadmium	31 different states with 70% of capacity located in Ohio, PA, IL, TX, MI, and Indiana	On- and off-site open dumping; sludge disposal in lagoons or surface impoundments	P	NA
Spent pickle liquor from steel finishing operations	K062	3312	C,T	Liquid	chromium, lead	34 different states with 70% of PA, OH, IL, IN, MI	Receiving body of water unlined lagoons, deep-well disposal, POTWs	P	NA
Non-Ferrous Smelting and Refining Industry									
Acid blowdown slurry/sludge resulting from the thickening of blowdown slurry from primary copper production	K064	3331	T	Aqueous sludge	lead, cadmium	Anaconda, MT; Hayden, Casa Grande, Miami, San Manuel, Morenci, Douglas and Ajo, AZ: El Paso, TX; Tacoma, WA; Copper Hill, TN; White Pine, MI; Garfield, UT; Hurley and Hidalgo, NM: McGill, NV	Settling lagoon: effluent is discharge to a tailings pond	P	NA

Table D-5. (Continued)

Hazardous Waste	Ident. Codes		Characteristics				Management Methods		
	EPA No. (Part 261)	Sic Code	Hazard Code	Physical State	Hazardous Constituents	Geographic Distribution	Present Practices	Incineration	
								Potential	Type
Surface impoundment - solids contained in and dredged from surface impoundments at primary lead smelting facilities	K065	3332	T	Slurries and sludges	lead, cadmium	Missouri, Idaho	Unlined surface impoundments; settled solids are dredged and dumped on-site	P	NA
Sludge from treatment of process wastewater and/or acid plant blowdown from primary zinc production	K066	3333	T	Sludge	lead, cadmium	St. Louis, IL; Corpus Christi, TX; Silver King, Idaho, Bartlesville, OK; Palmerton and Monica, PA; Clarkesville, TN	On-site stockpiling; some used as winter road sand; landfilled; lined and unlined surface impoundments	P	NA
Electrolytic anodes slimes/sludges from primary zinc production	K067	3333		Solid	lead, cadmium	St. Louis, IL; Corpus Christi, TX; Silver King, Idaho, Batlesville, OK; Palmerton and Monica, PA; Clarkesville TN	On-site stockpiling; some used as winter road sand, landfilled; lined and unlined surface impoundments	P	NA
Cadmium plant leach residue (iron oxide) from primary zinc production	K068	3333	T	Solid	lead, cadmium	St. Louis, IL; Corpus Christi, TX; Silver King, Idaho, Bartlesville, OK; Palmerton and Monica, PA; Clarkesville, TN	On-site stockpiling; some used as winter road sand; landfilled; lined and unlined surface impoundments		
Emission control dust/sludge from secondary lead smelting	K069	3339 3341	T	Solid/sludge	chromium, lead, cadmium	27 States with most in the Great Lake States, Texas and Louisiana	Unlined lagoons	P	NA
Distillation light ends from production of phthalic anhydride from ortho-xylene	K093	2869	T	Organic liquid	Phthalic anhydride, maleic anhydride	Texas, California, New Jersey		G	LI,RK
Distillation bottoms from production of phthalic anhydride from ortho-xylene	K094	2869	T	Organic sludge	Phthalic anhydride	Texas, California, New Jersey		G	RK
Distillation bottoms from production of 1,1,1 trichloroethane	K095	2869	T	Organic liquid	1,1,2 trichloroethane, 1,1,1,2 tetrachloroethane, 1,1,2,2 tetrachloroethane	Freeport, Texas; Lake Charles, LA; Geisman, LA		F	LI,RK

Table D-5. (Continued)

Hazardous Waste	Ident. Codes		Characteristics				Management Methods		
	EPA No. (Part 261)	Sic Code	Hazard Code	Physical State	Hazardous Constituents	Geographic Distribution	Present Practices	Incineration	
								Potential	Type
Heavy ends from heavy ends column from production of 1,1,1 trichloroethane	K096	2869	T	Organic liquid	1,2 dichloroethane, 1,1,1 trichloroethane, 1,1,2 trichloroethane			F	LI,RK
Vacuum stripper discharge from the chlordane chlorinator in the production of chlordane	K097	2879	T	Organic liquid	Chlordane, heptachlor			F	LI,RK
Untreated process wastewater from production of toxaphene	K098	2879	T	Aqueous liquid	Toxaphene			P	NA
Untreated wastewaste from production of 2,4-D	K099	2879	T	Aqueous liquid	2,4 dichlorophenol, 2,4,6 trichlorophenol			P	NA
Waste leaching solution from acid leaching of emission control dust/sludge from secondary lead smelting	K100	3339 3341	T	Aqueous liquid	Hexavalent chromium, lead cadmium			P	NA

Hazard Code: T - Toxic; R - Reactive; C - Combustible
Incineration Potential: G - Good (Waste amenable to incineration); F - Fair (Waste may be incinerated); P - Poor (Waste not amenable to incineration)
Type: NA - Not Applicable - Waste is a poor candidate for incineration; LI - Liquid Injection; RK - Rotary Kiln; FBC - Fluidized Bed Combustor

Source: MITRE 1981.

Table D-6. Applicability of Available Incineration Processes to Incineration of Hazardous Waste by Type

Waste type	Rotary kiln[a]	Liquid injection	Fluidized bed[a]	Multiple hearth	Coincineration	Starved air combustion/ pyrolysis
Solids:						
Granular, homogeneous	X		X	X	X	X
Irregular, bulky (pallets, etc.)	X				X	X[b]
Low melting point (tars, etc.)	X	X[c]	X		X	X
Organic compounds with fusible ash constituents	X			X	X	X
Unprepared, large, bulky material	X					
Gases:						
Organic vapor laden	X[d]	X[d]	X[d]	X[d]	X[d]	X[d]
Liquids:						
High organic strength aqueous wastes, often toxic	X[e]	X	X		X	
Organic liquids	X[e]	X	X		X	
Solids/liquids:						
Waste contains halogenated aromatic compounds (2,200°F minimum)	X	X[f]			X	
Aqueous organic sludges	X[g]		X	X	X	

[a] Suitable for pyrolysis operation.

[b] Handles large material on a limited basis.

[c] If material can be melted and pumped.

[d] If properly presented to the incinerator.

[e] If equipped with auxiliary liquid injection nozzles.

[f] If liquid.

[g] Provided waste does not become sticky upon drying.

Source: Monsanto 1981.

Table D-7. Compilation of HWDMS Data[a]

Type of hazardous waste facility	Number of facilities by EPA Region										
	I	II	III	IV	V	VI	VII	VIII	IX	X	Total
Facilities that store or treat H.W., but have other processes	756	1348	907	1647	1974	1117	345	165	853	55	9167
Facilities that only store or treat H.W.	536	1015	641	1128	1419	668	248	88	650	44	6437
Facilities that incinerate H.W.	54	73	76	105	112	101	26	16	33	1	597
Facilities that treat or store H.W. in surface impoundments	89	122	107	294	196	370	36	54	94	4	1366
Facilities that dispose of H.W. by:											
Landfill	35	49	57	94	90	124	11	32	36	3	531
Injection Well	5	10	1	12	25	85	5	3	5	0	151
Surface Impoundment	24	15	28	73	37	115	15	15	34	4	360
Land Application	4	11	6	50	29	62	12	20	26	1	221
Ocean Disposal	0	10	0	1	0	1	0	0	4	0	16
Disposal Total	68	95	92	230	181	387	43	71	105	8	1280

[a] Note that these numbers represent the number of valid applications which may not be equal to the number of sites currently in operation.

Source: Anon. 1982, Hazardous Waste News.

Table D-8. Industries Subject to Effluent Limitation Guidelines and Pretreatment Standards

Industry
Adhesives and sealants
Aluminum forming
Battery manufacturing
Coil coating
Copper forming
Electric and electronic components
Foundries
Inorganic chemicals
Iron and steel manufacturing
Leather tanning and finishing
Metal finishing
Nonferrous metals
Nonferrous metals forming
Ore mining
Organic chemicals, plastics, synthetic materials
Pesticides
Petroleum refining
Pharmaceuticals
Plastics molding and forming
Porcelain enameling
Pulp and paper
Steam electric
Textile mills
Timber products processing

APPENDIX E

AUXILIARY INFORMATION ON LANDFILLS AND LAND TREATMENT

APPENDIX E

AUXILIARY INFORMATION ON LANDFILLS AND LAND TREATMENT

Table E-1. Estimation of U.S. Population in Environmentally Sensitive Areas[a]

STATE	SMSAs LOCATED IN AN ESA	SMSA POPULATION[a]	TOTAL SMSA POPULATION IN ESAs[a]	STATE POPULATION[a]	REMAINDER OF STATE POPULATION[a] (Column 5 minus Col. 3)	PERCENTAGE OF STATE AREA IN ESAs	REMAINDER OF STATE POPULATION IN ESAs[a] (Column 7 Times Col. 6)	TOTAL STATE POPULATION IN ESAs[a] (Column 8 Plus Col. 4)
Maine	None		0	1,047	1,047	40	419	419
New Hampshire	None		0	808	808	5	40	40
Vermont	None		0	470	470	5	24	24
Massachusetts	Boston Worcester	2,898 377	3,275	5,800	2,525	30	758	4,033
Rhode Island	None		0	937	937	0	0	0
Connecticut	Bridgeport New Haven	397 415	812	3,088	2,276	40	910	1,722
New York	Albany, Schenectady, Troy Binghamton Buffalo Nassau New York City Rochester Syracuse	267[b] 151[c] 1,345 2,630 9,739 972 643	15,747	18,214	2,961	30	888	16,635

Table E-1. (Continued)

STATE	SMSAs LOCATED IN AN ESA	SMSA POPULATION[a]	TOTAL SMSA POPULATION IN ESAs[a]	STATE POPULATION[a]	REMAINDER OF STATE POPULATION[a]	PERCENTAGE OF STATE AREA IN ESAs	REMAINDER OF STATE POPULATION IN ESAs[a]	TOTAL STATE POPULATION IN ESAs[a]
New Jersey	Jersey City	598	3,592	7,325	3,733	15	560	4,152
	Long Branch	480						
	Newark	2,053						
	Paterson	461						
Pennsylvania	Harrisburg	425	8,540	11,862	3,322	40	1,329	9,869
	Johnstown	266						
	Lancaster	335						
	Philadelphia	4,806						
	Pittsburgh	2,365						
	York	343						
Ohio	Akron	677	5,529	10,737	5,208	25	1,302	6,831
	Canton	406						
	Cincinnati	1,383						
	Cleveland	2,006						
	Columbus	1,057						
Indiana	Evansville	290	1,708	5,330	3,622	40	1,449	3,157
	Indianapolis	1,137						
	South Bend	281						
Illinois	Chicago	7,002	7,624	11,131	3,507	40	1,403	9,027
	Peoria	351						
	Rockford	271						
Michigan	Detroit	4,446	6,215	9,098	2,883	100	2,883	9,098
	Flint	517						
	Grand Rapids	553						
	Kalamazoo	261						
	Lansing	438						

Table E-1. (Continued)

STATE	SMSAs LOCATED IN AN ESA	SMSA POPULATION[a]	TOTAL SMSA POPULATION IN ESAs[a]	STATE POPULATION[a]	REMAINDER OF STATE POPULATION[a]	PERCENTAGE OF STATE AREA IN ESAs	REMAINDER OF STATE POPULATION IN ESAs[a]	TOTAL STATE POPULATION IN ESAs[a]
Wisconsin	Oshkosh Madison Milwaukee	281 301 1,417	1,999	4,566	2,567	100	2,567	4,566
Minnesota	Duluth Minnesota	264 2,000	2,264	3,197	933	88	1,821	3,085
Iowa	Davenport Des Moines	365 325	690	2,855	2,165	50	1,083	1,773
Missouri	St. Louis	2,391	2,391	4,777	2,386	30	716	3,107
North Dakota	None		0	637	637	60	382	382
South Dakota	None		0	682	682	48	327	327
Nebraska	Omaha	575	575	1,543	968	28	271	846
Kansas	Kansas City	1,299	1,299	2,270	971	28	272	1,572
Delaware	None		0	573	573	0	0	0
Maryland	Baltimore	2,120	2,120	4,094	1,974	22	434	2,554
Wash., D.C.	None		0	723	723	0	0	0
Virginia	Newport Norfolk	347 745	1,092	4,908	3,816	15	572	1,664
West Virginia	Huntington	291	291	1,791	1,500	67	1,005	1,296

Table E-1. (Continued)

STATE	SMSAs LOCATED IN AN ESA	SMSA POPULATION[a]	TOTAL SMSA POPULATION IN ESAs[a]	STATE POPULATION[a]	REMAINDER OF STATE POPULATION[a]	PERCENTAGE OF STATE AREA IN ESAs	REMAINDER OF STATE POPULATION IN ESAs[a]	TOTAL STATE POPULATION IN ESAs[a]
N. Carolina	Charlotte Greensboro Raleigh	588 757 458	1,803	5,363	3,560	63	2,243	4,046
S. Carolina	Columbia Greenville Charleston	349 509 352	1,210	2,784	1,574	40	630	1,840
Georgia	None		0	4,882	4,882	65	3,173	3,173
Florida	Ft. Lauderdale Jackson Lakeland Miami Orlando Pensacola Tampa W. Palm Beach	756 661 255 1,370 549 259 1,276 412	5,538	8,090	2,552	100	2,552	8,090
Kentucky	Lexington Louisville	282 886	1,168	3,357	2,189	35	766	1,934
Tennessee	Chattanooga Knoxville Memphis	389 427 863	1,679	4,129	2,450	50	1,225	2,904
Alabama	Mobile	389	389	3,357	2,968	52	1,543	1,932
Mississippi	Jackson	275	275	2,324	2,049	85	1,742	2,017
Arkansas	Little Rock	350	350	2,062	1,712	82	1,404	1,754

Table E-1. (Continued)

STATE	SMSAs LOCATED IN AN ESA	SMSA POPULATION[a]	TOTAL SMSA POPULATION IN ESAs[a]	STATE POPULATION[a]	REMAINDER OF STATE POPULATION[a]	PERCENTAGE OF STATE AREA IN ESAs	REMAINDER OF STATE POPULATION IN ESAs[a]	TOTAL STATE POPULATION IN ESAs[a]
Louisiana	Baton Rouge	402	1,828	3,764	1,936	100	1,936	3,764
	New Orleans	1,083						
	Shreveport	343						
Oklahoma	Oklahoma City	750	1,322	2,709	1,387	100	1,387	2,709
	Tulsa	572						
Texas	Austin	375	6,757	12,050	5,293	30	1,588	8,345
	Beaumont	102						
	Corpus Christi	298						
	Dallas	2,464						
	El Paso	390						
	Houston	2,168						
	San Antonio	960						
Montana	None		0	735	735	15	110	110
Idaho	None		0	799	799	20	160	160
Wyoming	None		0	359	359	8	287	287
Colorado	None		0	2,496	2,496	15	374	374
New Mexico	Albaquerque	376	376	1,122	746	23	172	548
Arizona	Phoenix	1,127	1,543	2,153	610	10	61	1,604
	Tuscon	416						
Utah	Salt Lake City	753	753	1,173	420	35	147	900
Nevada	Las Vegas	308	308	573	265	33	87	395

Table E-1. (Continued)

STATE	SMSAs LOCATED IN AN ESA	SMSA POPULATION[a]	TOTAL SMSA POPULATION IN ESAs[a]	STATE POPULATION[a]	REMAINDER OF STATE POPULATION[a]	PERCENTAGE OF STATE AREA IN ESAs	REMAINDER OF STATE POPULATION IN ESAs[a]	TOTAL STATE POPULATION IN ESAs[a]
Washington	Seattle	1,383						
	Spokane	301	2,076	3,476	1,400	20	280	2,356
	Tacoma	392						
Oregon	Portland	1,062	1,062	2,266	1,204	28	337	1,399
California	Anaheim	1,597						
	Bakersfield	336						
	Fresno	435						
	Los Angeles	6,924						
	Oxnard Simi Valley	420	15,693	20,907	5,214	20	1,043	16,736
	Sacramento	864						
	Salinas	255						
	San Francisco	3,143						
	San Jose	1,157						
	Stockton	299						
	Vallejo	263						
Alaska	None		0	337	337	40	134	134
Hawaii	Honolulu	686	686	847	161	90	145	831
	Total U.S. Population in Environmentally Sensitive Areas							154,545

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a. In thousands. SMSA denotes Standard Metropolitan Statistical Area.
b. One-third of total SMSA population.
c. One-half of total SMSA population.
Source: USEPA 1980f.

Table E-2. Selected Data on Landfills from 1981 Waste Age Survey[a]

State	Number of all landfills in the state in 1981[b]	Number of NPDES permits in force for discharge of precipitation runoff[c]	Number of sites by tons per day operating capacity[b]					
			0–50 tpd	50–100 tpd	100–200 tpd	200–500 tpd	500–1,000 tpd	>1,000 tpd
Alabama	146	0	35	66	26	10	3	6
Alaska	80	DNA	DNA	DNA	DNA	DNA	DNA	DNA
Arizona	130	0	74	26	1	6	5	3
Arkansas	490	0	NA	NA	NA	NA	NA	NA
California	450	DNA	DNA	DNA	DNA	DNA	DNA	DNA
Colorado	205	15	200	3	2			
Connecticut	170	12	122	40	4	2	0	2
Delaware	NA	DNA	DNA	DNA	DNA	DNA	DNA	DNA
Florida	209	1	121	31	21	19	12	5
Georgia	517	NA	NA	NA	NA	NA	NA	NA
Hawaii	24	0	NA	NA	NA	NA	NA	NA
Idaho	220	0	71	8	1			
Illinois	260	2	30	20	50	100	40	20
Indiana	149	0	NA	NA	NA	NA	NA	NA
Iowa	NA	0	NA	NA	NA	NA	NA	NA
Kansas	243	0	82	12	13	8	4	0
Kentucky	210	0	UNK	UNK	UNK	UNK	UNK	UNK

Table E-2. (Continued)

State	Number of all landfills in the state in 1981[b]	Number of NPDES permits in force for discharge of precipitation runoff[c]	Number of sites by tons per day operating capacity[b]					
			0-50 tpd	50-100 tpd	100-200 tpd	200-500 tpd	500-1,000 tpd	>1,000 tpd
Louisiana	NA	1	2860	20	15	20	10	25
Maine	336	0	328	5	2	1	0	0
Maryland	NA	DNA	DNA	DNA	DNA	DNA	DNA	DNA
Massachusetts	286	0	4					
Michigan	470	NA	NA	NA	NA	NA	NA	NA
Minnesota	371	0	NA	NA	NA	NA	NA	NA
Mississippi	286	0	NA	NA	NA	NA	NA	NA
Missouri	107	1	87	17	7	5	4	0
Montana	221	0	216	4	3			
Nebraska	277	0	27	1	1	0	4	0
Nevada	114	0	109	1	2	0	1	1
New Hampshire	450	NA	405	29	10	6	0	0
New Jersey	240	DNA	175	11	13	22	5	14
New Mexico	228	0	UNK	UNK	UNK	UNK	UNK	UNK
New York	641	3	NA	NA	NA	NA	NA	NA
North Carolina	170	NA	UNK	UNK	UNK	UNK	UNK	UNK
North Dakota	84	0	NA	NA	NA	NA	NA	NA

Table E-2. (Continued)

State	Number of all landfills in the state in 1981[b]	Number of NPDES permits in force for discharge of precipitation runoff[c]	Number of sites by tons per day operating capacity[b]					
			0–50 tpd	50–100 tpd	100–200 tpd	200–500 tpd	500–1,000 tpd	>1,000 tpd
Ohio	680	2	UNK	UNK	UNK	UNK	UNK	UNK
Oklahoma	215	0	NA	NA	NA	NA	NA	NA
Oregon	226	1	205	10	0	3	0	2
Pennsylvania	1400	NA	NA	NA	NA	NA	NA	NA
Rhode Island	35	0	NA	NA	NA	NA	NA	NA
South Carolina	128	DNA	DNA	DNA	DNA	DNA	DNA	DNA
South Dakota	30	0	25	2	3	0	0	0
Tennessee	134	0	68	29	21	10	2	4
Texas	250	0	NA	NA	NA	NA	NA	NA
Utah	300	0	NA	NA	NA	NA	NA	NA
Vermont	73	0	73	0	0	0	0	0
Virginia	NA	DNA	DNA	DNA	DNA	DNA	DNA	DNA
Washington	NA	3	85	15	10	8	4	4

Table E-2. (Continued)

State	Number of all landfills in the state in 1981[b]	Number of NPDES permits in force for discharge of precipitation runoff[c]	Number of sites by tons per day operating capacity[b]					
			0-50 tpd	50-100 tpd	100-200 tpd	200-500 tpd	500-1,000 tpd	>1,000 tpd
West Virginia	228	0	NA	NA	NA	NA	NA	NA
Wisconsin	1050	0	575	100	150	150	70	5
Wyoming	NA	DNA	DNA	DNA	DNA	DNA	DNA	DNA
TOTALS	12,533	41	6,282	450	370	370	164	91

[a] NA means data not available. DNA means did not apply. UNK means unknown.

[b] Numbers in columns do not always add up to the total number of landfills in a state; this probably results from errors in the survey data.

[c] Not all states require landfills to have National Pollution Discharge Elimination System (NPDES) permits.

Source: Anon. 1981c, Waste Age Survey.

Table E-3. Input Data for SESOIL[a]

Climatological data

Latitude; (L;°N)

Average annual soil surface temperature (T;°C)

Average annual fraction of sky covered by clouds; (NN;-)

Average annual relative humidity (fractional); (S;-)

Average annual shortwave albedo of the surface; (A;-)

Average daily evapotranspiration; (REP;cm/day)

Mean monthly or annual precipitation; (MPA/cm)

Mean monthly annual storm duration; (MIR;days)

Mean number of storms per month or per year; (MN;-)

Mean length of rainy season with a month or year (MT;days)

Soil data

Soil bulk density; (RS;g/cm^3)

Intrinsic average soil permeability; (K1;cm^2)

Soil pore disconnectedness index; (c;-)

Effective soil porosity; (N;cm^3/cm^3)

Organic carbon content of the soil; (oc;%), and

Clay content of the soil; (cc;%)

Soil cation exchange capacity (CEC;m.e./100g/ dry w.t. soil)

Intrinsic soil permeability of upper soil layer; (K1U;cm^2)

Intrinsic oil permeability of middle soil layer; (K1M;cm^2)

Intrinsic soil permeability of lower soil layer; (K1M;cm^2

Chemical data

Solubility of compound (LS/ug/mL or mg/LO

Adsorption coefficient of the compound based on organic carbon (KOC;(ug/g oc)(ug/mL)

Diffusion coefficient of pollutant in air; (DA/cm^2/s)

Degradation rate in the upper unsaturated soil zone; (KDE;day^{-1})

Henry's Law Constant of the compound; (H;m^3•atm/mol)

Overall adsorption coefficient of compound on soil; (K;(ug/g soil)/(ug/mL)

Molecular weight of compound; (MWT;g/mol)

Valence of compound; (VAL;-)

Neutral hydrolysis constant (KNH;day^{-1})

Base hydrolysis constant (KBH;L/(mol•day))

Acid Hydrolysis constant (KAH;L/(mol•day))

Stability constant of compound-ligand complex (SK;-)

Number of moles of ligand per mole of compound complexed (B;-)

Molecular weight of ligand; (MWTLIG;g/mol)

Table E-3. (Continued)

Application-related geometric parameters
Area of the soil compartment (AR;cm^2)
Depth of groundwater (Z;m)
Depth of the upper soil zone (DU;cm)
Depth of the middle soil zone^b (DM;cm)
Depth of the lower soil zone (DL;cm)

Application-specific parameters
Ratio of biodegradation, middle/upper soil zone^b; (A2KDE;-)
Ratio of organic carbon content, middle/upper soil zone^b (AZOC;-)
Ratio of clay content, middle/upper soil zone^b; (A2CC;-)
Ratio of biodegradation, lower/upper soil zone; (AKDE;-)
Ratio of organic carbon content, lower/upper soil zone (AOC;-)
Ratio of clay content, lower/upper soil zone (ACC;-)
Ratio of concentration of pollutant in rainfall to maximum solubility for chemicals applied to the soil surface only (ASL;-)
Freundich isotherm exponent (FRN;-)
pH in upper soil zone (PH;-)
Ratio of pH, middle/upper^b (A2PH;-)
Ratio of CEC, middle/upper^b (A2CEC;-)
Ratio of pH, lower/upper (APH;-)

Application-specific parameters (continued)
Ratio of CEC, lower/upper (ACEC;m-)
Soil moisture^c; (THA;-)
Infiltration^c; (IA;cm)
Groundwater recharge^c (RGA;cm)
Surface runoff^c; (RSA;cm)
Initial concentration of pollutant in the upper zone soil moisture (CUM;ug/mL)
Initial concentration of pollutant in the middle zone soil moisture^b; (CMM;ug/mL)
Initial concentration of pollutant in the lower zone soil moisture; (CLM;ug/mL)
Monthly loading in the upper soil zone; (POLINU;ug/cm^2)
Monthly loading in the middle soil zone^b; (POLINM;ug/cm^2)
Monthly loading in the lower soil zone (POLINL;ug/cm^2)
Index for pollutant in surface runoff by month or year (ISRM/ISRA;-)
Rate of additional, unspecified pollutant transformation in the upper zone^b; (TRANSM;ug/cm^2/month)
Rate of additional, unspecified pollutant transformation in the middle zone^b; (TRANSM;ug/cm^2/month)
Rate of additional, unspecified pollutant transformation in the lower zone (TRANSL;ug/cm^2/month)
Pollutant loss to unspecified sink in the upper zone (SINKU;ug/cm^2/month)

Table E-3. (Continued)

Application specific parameters (continued)
Pollutant loss to unspecified sink in the middle zone[b] (SINKM;ug/cm^2/month)
Pollutant loss to unspecified sink in the lower zone (SINKL;ug/cm^2/month)
Ligand mass input to upper zone[d]; (LIGU;ug/cm^2)
Ligand mass input to middle zone[b,d]; (LIGM;ug/cm^2)
Ligand mass input to lower zone[d]; (LIGU;ug/cm^2)

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[a] Not all parameters are required for all applications.

[b] Required only for simulations involving 2 soil zones.

[c] Required if the user prespecifies a hydrologic budget.

[d] Only used for simulations involving metals.

Source: Bonazountas and Wagner 1981.

Table E-4. Geographic Distribution, by Region and State, of Hazardous Waste Land Treatment Sites in the U.S.

Region	Regional Office	Number of facilities
VI	Dallas, Texas	58
IV	Atlanta, Georgia	45
IX	San Francisco, California	19
VIII	Denver, Colorado	18
V	Chicago, Illinois	16
VII	Kansas City, Missouri	15
X	Seattle, Washington	12
II	New York City, New York	8
III	Philadelphia, Pennsylvania	7
I	Boston, Massachusetts	0

State or territory	Number of facilities
Texas	29
California	18
Louisiana	13
Oklahoma	11
Ohio	9
Alabama	8
Kansas	8
Washington	8
Florida	7
Georgia	7
Mississippi	7
Montana	6
North Carolina	6
Wyoming	6
South Carolina	5
Missouri	4
Puerto Rico	4
Colorado	3
Illinois	3
Kentucky	3
New Mexico	3
Utah	3
Arkansas	2
Indiana	2
Iowa	2
New Jersey	2
Maryland	2
Minnesota	2
Pennsylvania	2
Tennessee	2
Virginia	2
Alaska	1
Delaware	1
Guam	1
Idaho	1
Michigan	1
Nebraska	1

Table E-4. (Continued)

State or territory	Number of facilities
New York	1
Oregon	1
Virgin Islands	1
American Samoa	0
Arizona	0
Commonwealth of the Northern Marianas	0
Connecticut	0
District of Columbia	0
Hawaii	0
Maine	0
Massachusetts	0
Nevada	0
New Hampshire	0
North Dakota	0
Rhode Island	0
South Dakota	0
Vermont	0
West Virginia	0
Wisconsin	0

Source: USEPA 1983a.

Table E-5. Industrial Classification and Location of Hazardous Waste Land Treatment Facilities

SIC Code		Region	State	Landfarm Facility
025	Poultry Feed	IV	Tennessee	Arapahoe Chemicals Inc.
1321	Natural Gas Proc.	VI	Louisiana	Gulf Oil Corp.
1389	Oil & Gas Services	IX	California	IT Corp. - Benson Ridge Facility
203	Fruit Processing	IV	Florida	Ben Hill Griffin, Inc.
		IV	Florida	Holly Hill Fruit Products Co.
		IV	Florida	Orange Co. of Florida, Inc.
2067	Chewing Gum Manu.	IV	Georgia	Wm. Wrigley, Jr. Co.
222	Weaving Mills, Synthetics	III	Maryland	Tenneco Chemicals, Inc.
		IV	Georgia	Southern Mills Inc. Senola Div.
229	Misc. Textile Goods	IV	North Carolina	Finetex Inc. - Southern Div.
		IV	South Carolina	Sandoz Inc. Martin Works
249	Misc. Wood Products	IV	North Carolina	U.S. Industries, Inc.
2491	Wood Preserving	IV	Alabama	Brown Wood Preserving Co., Inc.
		IV	Alabama	T. R. Miller Co., Inc.
		IV	Mississippi	Coppers
		IV	Mississippi	Pearl River Wood Preserving Corp.
		VI	Texas	Kerr-McGee Chemical Corp.
		VII	Missouri	Kerr-McGee Chemical Corp.
2600	Paper & Allied Products	X	Washington	Boise Cascade/Paper Group
2611	Pulp Mills	V	Michigan	Simpson Paper Co.
2621	Paper Mills	V	Mississippi	Simpson Paper Co.
2819	Industrial Inorganic Chemicals	VI	Louisiana	Texaco USA (Div. of Texaco Inc.)
		VI	Texas	American Petrofina Co. of Texas & Cosden Oil & Chemical
2821	Plastics, Materials & Resins	VI	Louisiana	Shell Oil Co.
		VI	Texas	Reichold Chemicals
		VI	Texas	Union Carbide Corp.
2834	Pharmaceutical Preparations	IV	Tennessee	Arapahoe Chemicals Inc.
2851	Paints & Allied Products	IV	Georgia	Glidden C&R Div. of SCM Corp.
		VII	Iowa	Landfill Service Corp.
		IX	California	Environmental Protection Corp. - Westside Disposal Farm
2865	Cyclic Crudes & Intermediates	VI	Arkansas	Arkansas Eastman Co.
2869	Industrial Organic Chemicals	VI	Arkansas	Arkansas Eastman Co.
		VI	Louisiana	Chevron Chemical Co.
		VI	Louisiana	Exxon Co. USA Baton Rouge Refinery
		VI	Oklahoma	Conoco Inc. Ponca City
		VI	Texas	Celanese Tract K

Table E-5. (Continued)

SIC Code		Region	State	Landfarm Facility
2869	Industrial Organic Chemicals (continued)	VI	Texas	Reichold Chemicals
		VI	Texas	Union Carbide Corp.
		VII	Missouri	Syntex Agribusiness Inc.
		IX	California	Shell Oil Co. - Martinez Manu. Complex
2873	Nitrogenous Fertilizers	VI	Texas	Cominco American Inc. Camex Operations
		VII	Iowa	Chevron Chemical Co.
		VII	Missouri	Atlas Powder Co., Atlas Plant
2874	Phosphatic Fertilizers	VII	Iowa	Chevron Chemical Co.
2875	Fertilizers, Mixing Only	IX	California	Environmental Protection Corp. - Westside Disposal Farm
		X	Washington	Phillips Pacific Chemical Co.
2879	Agricultural Chemicals	IV	Georgia	Union Carbide Agricultural Co. Inc.
289	Misc. Chemical Products	IV	South Carolina	Abco Industries Inc.
		IV	South Carolina	Carolina Eastman Co. (Div. of Eastman Kodak)
2892	Explosives	IV	Alabama	Hercules, Inc.
		VII	Missouri	Atlas Powder Co., Atlas Plant
29	Petroleum Production	IV	Alabama	Plantation Pipeline Co., HE Facility
		IV	Mississippi	Plantation Pipeline Co.
		VII	Nebraska	Offutt Air Force Base
		IX	California	Union Oil Co. of CA - Santa Maria Refinery
2911	Petroleum Refinery	II	New Jersey	Exxon Refinery
		II	New Jersey	Texaco U.S.A.
		II	Virgin Islands	Hess Oil Virgin Islands Corp.
		III	Delaware	Getty Refining & Marketing Co.
		III	Maryland	Chevron U.S.A., Inc.
		III	Pennsylvania	Arco Petroleum Products Co.
		III	Virginia	Amoco Oil Co.
		III	Virginia	Hercules, Inc.
		IV	Alabama	Hunt Oil Co., Tuscaloosa Refinery
		IV	Georgia	Amoco Oil Co. Savannah Refinery
		IV	Mississippi	Amerada Hess Corp.
		IV	Mississippi	Rogers Rental & Landfill - Exxon
		V	Illinois	Marathon Oil
		V	Indiana	Indiana Farm Bureau Coop. Assoc.
		V	Indiana	Rock Island Refining Corp.
		V	Minnesota	Koch Refinery
		V	Ohio	Fondessey Enterprise LF Site #2
		V	Ohio	Fondessey Enterprise LF Site #3
		V	Ohio	Fondessey Enterprise LF Site #4
		V	Ohio	Gulf Oil Co. U.S.
		V	Ohio	Sunoco Refinery
		V	Ohio	Standard Oil Co.
		V	Ohio	Standard Oil Co. (Ohio)

Table E-5. (Continued)

SIC Code	Region	State	Landfarm Facility
2911 Petroleum Refinery (continued)	VI	Arkansas	Tosco Corp.
	VI	Louisiana	Cities Service Co.
	VI	Louisiana	Conoco Inc., Lake Charles Refinery
	VI	Louisiana	Exxon Co. U.S.A. Baton Rouge Refinery
	VI	Louisiana	Gulf Oil Co. - U.S.
	VI	Louisiana	Gulf Oil Corp.
	VI	Louisiana	Marathon Oil Co. LA Refining Div.
	VI	Louisiana	Murphy Oil Corp.
	VI	Louisiana	Plantation Pipeline Co.
	VI	Louisiana	Shell Oil Co.
	VI	Louisiana	Texaco U.S.A. (Div. of Texaco Inc.)
	VI	New Mexico	Shell Oil Co. Inc.
	VI	Oklahoma	Basin Refining Inc.
	VI	Oklahoma	Champlin Petroleum Co.
	VI	Oklahoma	Conoco Inc. Ponca City
	VI	Oklahoma	Hudson Refinery
	VI	Oklahoma	Kerr-McGee Refinery Corp.
	VI	Oklahoma	Sun Petroleum Products Co.
	VI	Oklahoma	Texaco U.S.A. (Div. of Texaco Inc.)
	VI	Oklahoma	Tosco Corp. - Duncan Refinery
	VI	Oklahoma	Vickers Petroleum Corp.
	VI	Texas	American Petrofina Co. of Texas & Cosden Oil & Chemical
	VI	Texas	Amoco Oil Co. Land Farm
	VI	Texas	Arco Petroleum Products Co.
	VI	Texas	Champlin Petroleum Co.
	VI	Texas	Coastal States Petroleum Co.
	VI	Texas	Cosden Oil
	VI	Texas	Crown Central Petroleum Corp.
	VI	Texas	Exxon Co. - Baytown Refinery & Chemical
	VI	Texas	Gulf Coast Waste Authority
	VI	Texas	Mobil Oil Corp.
	VI	Texas	Phillips Petroleum
	VI	Texas	Shell Oil Co. Odessa Refinery
	VI	Texas	Sigmor Refining Co.
	VI	Texas	Southwestern Refining Co. Inc.
	VI	Texas	Sun Oil Co. of Pennsylvania
	VI	Texas	Sweeney Refinery & Petrochem. Compl.
	VI	Texas	Texaco Inc. - Amarillo
	VI	Texas	Texaco Inc. - Pt. Arthur
	VI	Texas	Winston Refining Co.
	VII	Kansas	CRA, Inc. - Phillipsburg
	VII	Kansas	CRA, Inc. - Coffeyville
	VII	Kansas	Derby Refining Co.
	VII	Kansas	Getty Refining & Marketing Co.
	VII	Kansas	Kansas Industrial Waste Facility, Inc.
	VII	Kansas	Mobil Oil Corp.
	VII	Kansas	Pester Refining Co.
	VII	Kansas	Total Petroleum, Inc.
	VII	Missouri	Amoco Oil Co., Sugar Creek Refinery

Table E-5. (Continued)

SIC Code		Region	State	Landfarm Facility
2911	Petroleum Refinery (continued)	VIII	Colorado	Gary Refining Co.
		VIII	Montana	Conoco Oil Refinery
		VIII	Montana	Conoco Landfarm
		VIII	Montana	Exxon Billings Refinery
		VIII	Montana	Farmers Union Central Exchange/Cenex
		VIII	Montana	Phillips Great Falls
		VIII	Utah	Amoco Oil Co. SLC Tank Farm
		VIII	Utah	Husky Oil Co. of Delaware
		VIII	Utah	Phillips Petroleum Woods Cross Refinery
		VIII	Wyoming	Amoco Pipeline Tank Farm
		VIII	Wyoming	Husky Oil Co. of Delaware
		VIII	Wyoming	Little America Refining Co., Inc.
		VIII	Wyoming	Sinclair Oil Corp.
		VIII	Wyoming	Wyoming Refining Co.
		IX	California	Chevron U.S.A.
		IX	California	Environmental Protection Corp. - Eastside Disposal Farm
		IX	California	Environmental Protection Corp. - Westside Disposal Farm
		IX	California	IT Corp. - Benicia
		IX	California	IT Corp. - Martinez
		IX	California	IT Corp. - Montezuma Hills
		IX	California	IT Transportation Co. - Imperial
		IX	California	Shell Oil Co., Martinez Manu. Complex
		IX	California	Union Oil of California
		X	Oregon	Chem-Security Systems, Inc.
		X	Washington	Arco Petroleum Products Co.
		X	Washington	Mobil Oil Corp.
		X	Washington	Shell Oil Co.
		X	Washington	Texaco U.S.A. (Div. of Texaco, Inc.)
2969	Ind. Organic Chemicals	IX	California	Environmental Protection Corp. - Westside Disposal Farm
3011	Pneumatic Tire Manu.	VI	Oklahoma	Dayton Tire & Rubber Co.
3317	Steel Pipe & Tubing Manu.	VI	Texas	Quanex Corp. Gulf States Div.
3471	Plating & Polishing	IV	North Carolina	Neuse River Wastewater Treatment Plant
		VII	Iowa	Landfill Service Corp.
348	Ordnance & Accessories	IV	Florida	Olin Corp.
		IV	Kentucky	Lexington - Blue Grass Depot Activity
		X	Guam	Anderson AFB
		X	Idaho	Omark Industries, Inc.
3483	Ammunition	VI	Texas	Lone Star Army Ammunition Plant
349	Misc. Fabricated Metal Products	IV	Alabama	Reliable Metal Products, Inc.
		VI	New Mexico	Olman Heath Co.
3496	Misc. Fabricated Wire Products	IV	Georgia	Gilbert & Bennett Manu. Corp.
		VI	Texas	Roman Wire Co.

Table E-5. (Continued)

SIC Code		Region	State	Landfarm Facility
3498	Fabricated Pipe & Fittings	IV	Florida	Armco, Inc.
3533	Oil Field Machinery	VI	Oklahoma	Lee C. Moore Corp.
3589	Service Industry Machinery	IV	Georgia	General Electric Co.
		IV	South Carolina	General Electric Co.
3621	Motors & Generators	IV	Mississippi	American Bosch Electrical Products
3641	Electric Lamps	IV	North Carolina	General Electric Co.
3662	Radio & TV Communication Equipment	IX	California	The Grass Valley Group, Inc.
3679	Electronic Components	IV	Florida	Tropical Circuits, Inc.
		IX	California	Hughes Research Laboratories
3743	Railroad Equipment	IV	Alabama	Evans Transportation Co.
3999	Manufacturing Industries	II	New York	Borden Chemical A&C Division
		IV	Kentucky	Borden Chemical A&C
		IV	Kentucky	General Electric Co.
4441	Marine Terminal	VI	Louisiana	Conoco Inc., Lake Charles Refinery
4463	Marine Cargo Handling	VI	Louisiana	Texaco U.S.A. (Div. of Texaco Inc.)
49	Geothermal Energy Production	IX	California	IT Corp. - Benicia
		IX	California	IT Corp. - Montezuma Hills
		IX	California	IT Corp. - Martinez
		IX	California	IT Transportation Co. - Imperial
4953	Refuse Systems	III	Pennsylvania	G.R.O.W.S. Inc. Landfill
		V	Ohio	Cecos
		VI	Louisiana	Rollins Environmental Services
		VI	Louisiana	Shreveport Sludge Disposal Facility
		VI	Texas	Gulf Coast Waste Disposal Authority
		VI	Texas	Waste Disposal Center
		IX	California	Casmalia Disposal
		IX	California	Chemical Waste Management, Inc.
		IX	California	IT Corp. - Benson Ridge Facility
		IX	California	M. P. Disposal Co., Inc.
		IX	California	Simi Valley Sanitary Landfill
4990	Refuse Collection & Disposal	IX	California	Oakland Scavenger Co.
5171	Petroleum Terminal	VI	Louisiana	Texaco U.S.A. (Div. of Texaco Inc.)
7694	Armature Rewind Shop	VIII	Montana	General Electric Co.
7699	Repair & Related Services	VIII	Montana	General Electric Co.
8221	Colleges & Universities	VIII	Colorado	Colorado State University

Table E-5. (Continued)

SIC Code	Region	State	Landfarm Facility
9711 National Security	IV	Alabama	Maxwell AFB
	IV	Florida	Tyndall AFB
	IV	North Carolina	XVIII Airborne Corps & Fort Bragg
	IV	North Carolina	Seymour Johnson AFB
	IV	South Carolina	Shaw AFB
	IV	Tennessee	McGhee Tyson Air National Guard Base
	VI	New Mexico	White Sands Missile Range
	VIII	Colorado	U.S. Army
	X	Washington	Yakima Firing Center

Source: USEPA 1983a.

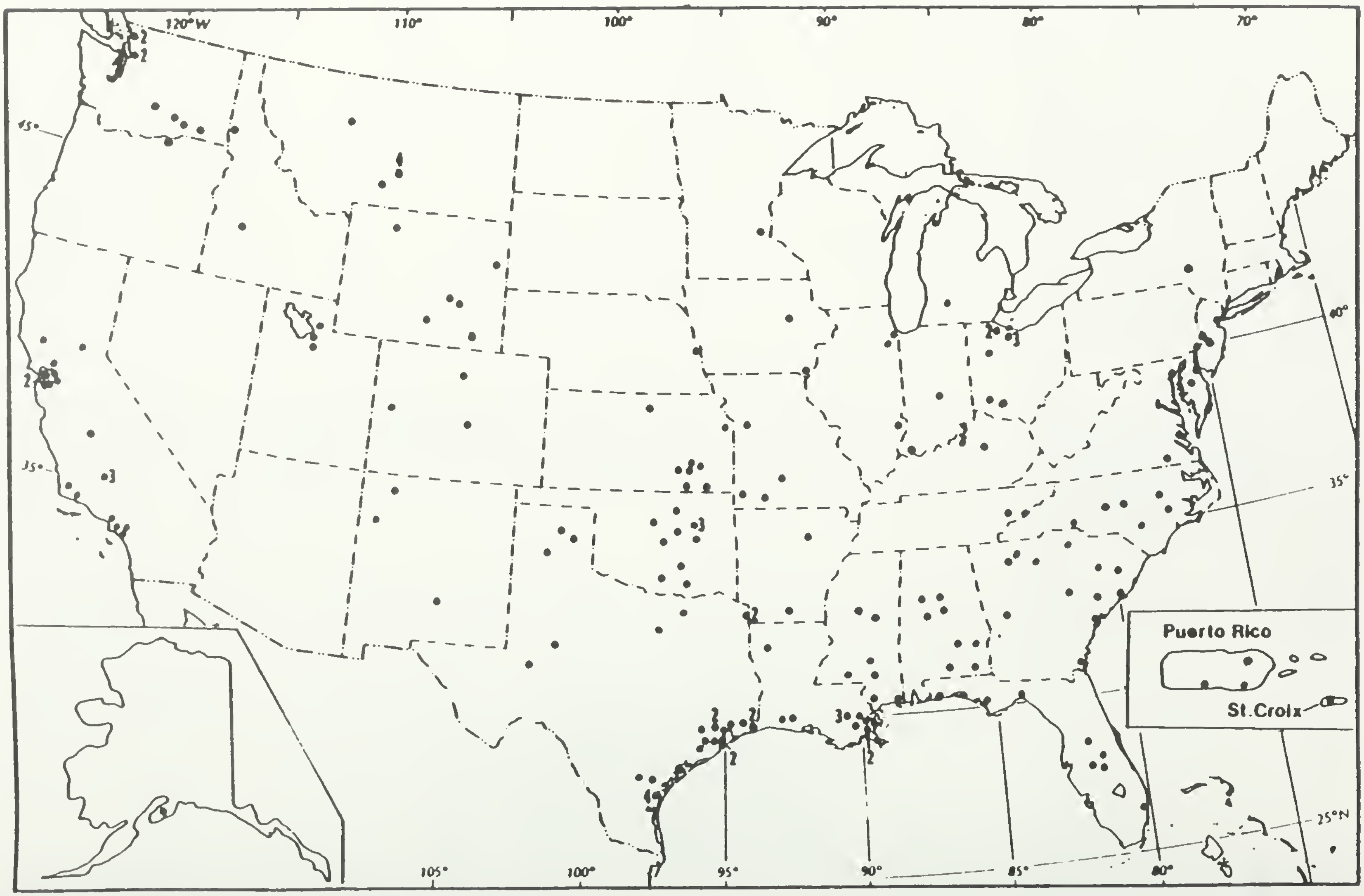

Figure E-1. Areal Distribution of Land Treatment Facilities

Source: USEPA 1983a.

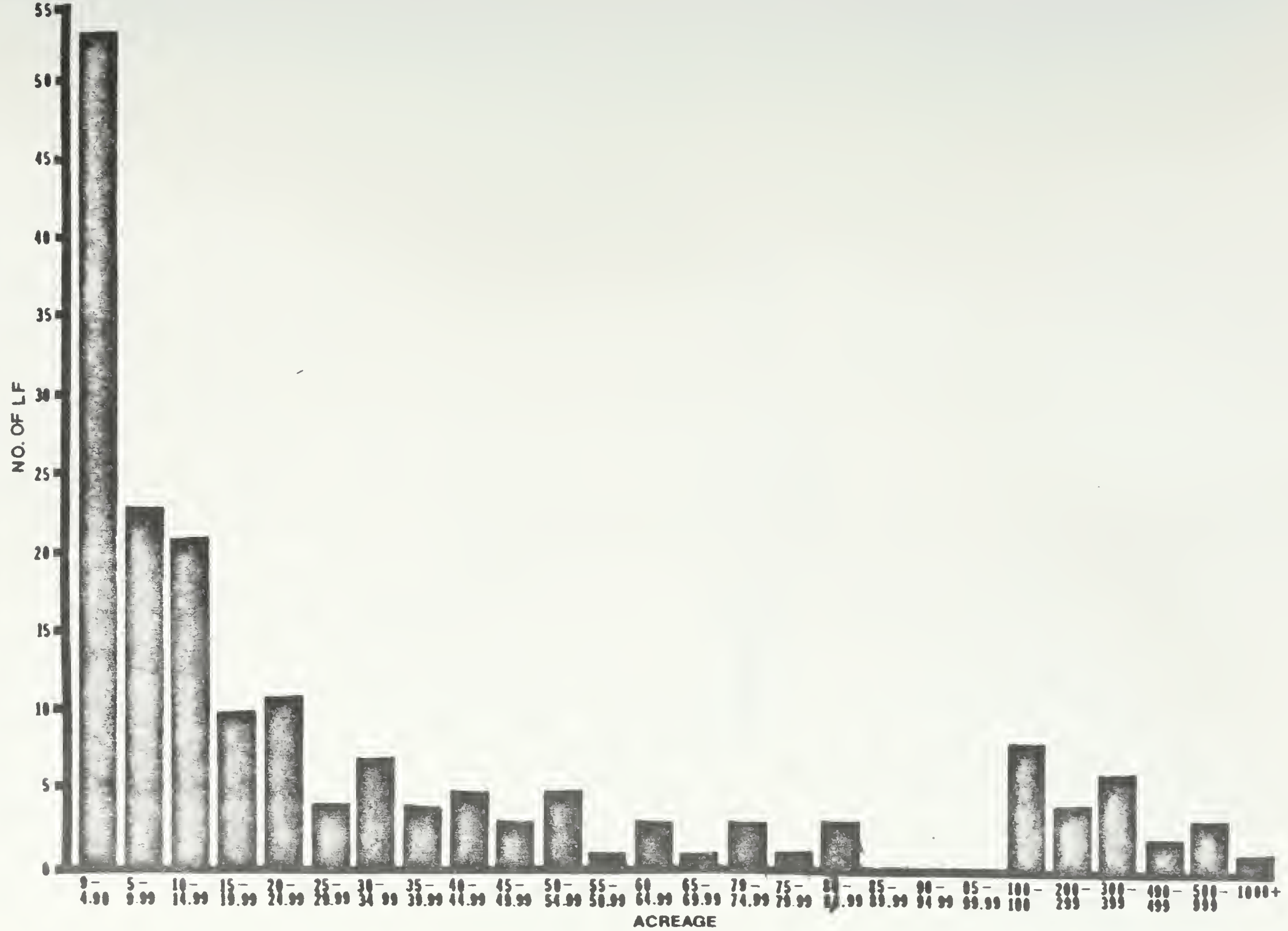

Figure E-2. Size Distribution of Hazardous Waste Land Treatment Facilities

Source: USEPA 1983a.

APPENDIX F

AUXILIARY INFORMATION ON GROUNDWATER

Table F-1. Computerized Groundwater Data Bases

Name	Geographic coverage	USGS contact/telephone number
Ground Water Site Inventory (GWSI)	All of U. S.	Kathy Hunt/703-860-6871
High Plains Regional Aquifer System Analysis (AQUIFERS)	Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, Wyoming	Richard Lucky/303-234-6017
Kansas Water Level File (KWL)[a]	Kansas	Jesse McNellis/913-843-0701
Annual Observation Well File (AOWF)	New Mexico	James Hudson/505-766-2011
New England District Ground Water Level Data Base (NEGWL)[a]	Entire New England USGS District	Robert Wakelee/617-223-2822
Northern High Plains File (NHP FILE)	Northern High Plain Area of New Mexico	John McLean/505-766-2810
Nebraska Registered Well File (NRWL)	Nebraska	Donald Schild/402-471-5082
Nebraska Water Level File (NWLF)	Nebraska	Donald Schild/402-471-5082
Hydrogeology Subfile (HY)	Long Island, New York	George Hawkins/516-938-8830
Mimbres Basin (MB FILE)	Mimbres Basin, New Mexico	John McLean/505-766-2810
Nevada Test Site and Vicinity Well Inventory (NTSWI)	Part of Southern Nevada and nearby California	Richard K. Waddell/303-234-2115
San Juan Development	San Juan Basin in Northwest New Mexico	Peter Frenzel/505-768-2810
Water Level Subfile (WL FILE)	Long Island, New York	George W. Hawkins/516-938-8830

[a] Data is included in the GWSI.

Source: USDI 1979.

Table F-2. Listing of State Geologists - 1983[a]

State	Name & Title	Address & Telephone No.
Alabama	Dr. Ernest A. Mancini State Geologist & Oil & Gas Board Supervisor (Ernie)	Geological Survey of Alabama P.O. Drawer O University, Alabama 35486 (205) 349-2852 FTS Direct
Alaska	Dr. Ross G. Schaff State Geologist (Ross)	Division of Geological and Geophysical Surveys 3001 Porcupine Drive Anchorage, Alaska 99501 (907) 274-9686 FTS Direct
Arizona	Dr. Larry D. Fellows State Geologist (Larry)	Bureau of Geology & Mineral Technology 845 N. Park Avenue Tucson, Arizona 85719 (602) 621-7906 FTS Direct
Arkansas	Mr. Norman F. Williams Director (Bill)	Arkansas Geological Commission 3815 West Roosevelt Road Little Rock, Arkansas 72204 (501) 371-1488 FTS 740-5011 (Operator)
California	Dr. James F. Davis State Geologist (Jim)	Department of Conservation California Division of Mines & Geology 1416 Ninth Street, Room 1341 Sacramento, California 95814 (916) 445-1923 FTS Direct
Colorado	Mr. John W. Rold Director & State Geologist (John)	Colorado Geological Survey 1313 Sherman Street Room 715 Denver, Colorado 80203 (303) 866-2611 FTS Direct

Table F-2. (Continued)

State	Name & Title	Address & Telephone No.
Connecticut	Dr. Hugo F. Thomas Director & State Geologist (Hugo)	Department of Environmental Protection Natural Resources Center 165 Capitol Avenue, Room 553 Hartford, Connecticut 06106 (203) 566-3540 FTS Direct
Delaware	Dr. Robert R. Jordan State Geologist (Bob)	Delaware Geological Survey University of Delaware 101 Penny Hall Newark, Delaware 19711 (302) 738-2833 FTS Direct
Florida	Mr. Charles W. Hendry, Jr. Chief (Bud)	Bureau of Geology 903 West Tennessee Street Tallahassee, Florida 32304 (904) 488-4191 FTS Direct
Georgia	Dr. William H. McLemore State Geologist (Bill)	Georgia Geologic Survey, Rm. 400 19 Martin Luther King Drive, S.W. Atlanta, Georgia 30334 (404) 656-3214 FTS Direct
Hawaii	Mr. Robert T. Chuck Manager-Chief Engineer (Bob)	Department of Land & Natural Resources Division of Water & Land Development P.O. Box 373 Honolulu, Hawaii 96809 (808) 548-7533
Idaho	Dr. Maynard M. Miller Chief (Maynard)	Bureau of Mines & Geology University of Idaho Campus Moscow, Idaho 83843 (208) 885-7991 FTS 554-1111 (Operator)
Illinois	Dr. Robert E. Bergstrom Chief (Bob)	Illinois State Geological Survey 615 East Peabody Drive, Room 121 Champaign, Illinois 61820 (217) 344-1481 FTS Direct
Indiana	Dr. John B. Patton State Geologist (John)	Indiana Geological Survey Department of Natural Resources 611 N. Walnut Grove Bloomington, Indiana 47405 (812) 335-2862 FTS Direct

Table F-2. (Continued)

State	Name & Title	Address & Telephone No.
Iowa	Mr. Donald L. Koch Director & State Geologist (Don)	Iowa Geological Survey 123 North Capitol Iowa City, Iowa 52242 (319) 338-1173 FTS Direct
Kansas	Dr. William W. Hambleton Director & State Geologist (Bill)	Kansas Geological Survey 1930 Avenue A, Campus West The University of Kansas Lawrence, Kansas 66044 (913) 864-3965 FTS Direct
Kentucky	Dr. Donald C. Haney Director & State Geologist (Don)	Kentucky Geological Survey University of Kentucky 311 Breckinridge Hall Lexington, Kentucky 40506 (606) 257-5863 FTS Direct
Louisiana	Dr. Charles G. Groat Director & State Geologist (Chip)	Louisiana Geological Survey Department of Natural Resources Box G, University Station Baton Rouge, Louisiana 70893 (504) 342-6754 FTS Direct
Maine	Dr. Walter Anderson Director & State Geologist (Walt)	Maine Geological Survey Department of Conservation State House, Station 22 Augusta, Maine 04333 (207) 289-2801 FTS Direct
Maryland	Dr. Kenneth N. Weaver Director (Ken)	Maryland Geological Survey The Rotunda 711 West 40th Street, Suite 440 Baltimore, Maryland 21211 (301) 338-7084 FTS 922-3311 (Operator)
Massachusetts	Mr. Joseph A. Sinnott State Geologist (Joe)	Department of Environmental Quality Engineering Division of Waterways 1 Winter St., 7th Floor Boston, Massachusetts 02108 (617) 292-5690 FTS Direct

Table F-2. (Continued)

State	Name & Title	Address & Telephone No.
Michigan	Mr. R. Thomas Segall State Geologist (Tom)	Geological Survey Division Michigan Department of Natural Resources Stevens T. Mason Building P.O. Box 30028 Lansing, Michigan 48909 (517) 373-1256 FTS Direct
Minnesota	Dr. Matt S. Walton Director (Matt)	Minnesota Geological Survey 2642 University Avenue St. Paul, Minnesota 55114 (612) 373-3372 FTS Direct
Mississippi	Mr. Alvin R. Bicker Director & State Geologist (Al)	Mississippi Geological, Economic & Topographical Survey P.O. Box 5348 Jackson, Mississippi 39216 (601) 354-6228 FTS Direct
Missouri	Dr. Wallace B. Howe Division Director & State Geologist (Wally)	Department of Natural Resources Division of Geology & Land Survey P.O. Box 250 Rolla, Missouri 65401 (314) 364-1752 FTS Direct
Montana	Dr. Edward C. Bingler Director & State Geologist	Montana Bureau of Mines & Geology Montana College of Mineral Science & Technology Butte, Montana 59701 (406) 496-4181 FTS 585-5011 (Operator)
Nebraska	Mr. Vincent H. Dreeszen Director (Vince)	Conservation & Survey Division The University of Nebraska Lincoln, Nebraska 68588 (402) 472-3471 FTS Direct
Nevada	Mr. John H. Schilling Director & State Geologist (John)	Nevada Bureau of Mines & Geology University of Nevada Reno, Nevada 89557-0088 (702) 784-6691 FTS 598-6011 (Operator)

Table F-2. (Continued)

State	Name & Title	Address & Telephone No.
New Hampshire	Dr. Robert I. Davis State Geologist (Bob)	Department of Resources & Economic Development 117 James Hall University of New Hampshire Durham, New Hampshire 03824 (603) 862-1216 FTS 834-7011 (Operator)
New Jersey	Mr. Frank Markewicz Acting State Geologist (Frank)	New Jersey Geological Survey Division of Water Resources CN-029 Trenton, New Jersey 08625 (609) 292-2576 FTS Direct
New Mexico	Dr. Frank E. Kottlowski Director (Frank)	New Mexico Bureau of Mines & Mineral Resources Campus Station Socorro, New Mexico 87801 (505) 835-5420 FTS Direct
New York	Dr. Robert Fakundiny State Geologist & Chief (Bob)	New York State Geological Survey State Science Service, Room 3140 Cultural Education Center Albany, New York 12230 (518) 474-5816 FTS Direct
North Carolina	Mr. Stephen G. Conrad Director & State Geologist (Steve)	Division of Land Resources Department of Natural Resources & Community Development P.O. Box 27687 Raleigh, North Carolina 27611 (919) 733-3833 FTS Direct
North Dakota	Dr. Don L. Halvorson State Geologist (Don)	North Dakota Geological Survey University Station, Box 8156-58202 Grand Forks, North Dakota 58201 (701) 777-2231 FTS 783-5771 (Operator)
Ohio	Mr. Horace R. Collins Division Chief & State Geologist (Buzz)	Ohio Division of Geological Survey Fountain Square Building B Columbus, Ohio 43224 (614) 265-6605 FTS Direct

Table F-2. (Continued)

State	Name & Title	Address & Telephone No.
Oklahoma	Dr. Charles J. Mankin Director (Charlie)	Oklahoma Geological Survey The University of Oklahoma 830 Van Vleet Oval, Rm. 163 Norman, Oklahoma 73019 (405) 325-3031 FTS 736-4011 (Operator)
Oregon	Dr. Donald A. Hull State Geologist (Don)	Department of Geology & Mineral Industries 1005 State Office Building Portland, Oregon 97201 (503) 229-5580 FTS Direct
Pennsylvania	Dr. Arthur A. Socolow State Geologist (Art)	Bureau of Topographic & Geologic Survey Department of Environmental Resources P.O. Box 2357 Harrisburg, Pennsylvania 17120 (717) 787-2169 FTS Direct
Rhode Island	Mr. Daniel W. Varin Chief	Statewide Planning Program 265 Melrose Street Providence, Rhode Island 02907 (401) 277-2656
South Carolina	Mr. Norman K. Olson State Geologist (Ole)	South Carolina Geological Survey Harbison Forest Road Columbia, South Carolina 29210 (803) 758-6431 FTS Direct
South Dakota	Mr. Merlin J. Tipton State Geologist (Tip)	South Dakota Geological Survey Science Center University of South Dakota Vermillion, South Dakota 57069 (605) 624-4471 FTS 782-7000 (Operator)
Tennessee	Mr. Robert E. Hershey State Geologist (Bob)	Department of Conservation Division of Geology 701 Broadway Nashville, Tennessee 37203 (615) 742-6691 FTS Direct

Table F-2. (Continued)

State	Name & Title	Address & Telephone No.
Texas	Dr. W. L. Fisher Director (Bill)	Bureau of Economic Geology The University of Texas at Austin University Station Box X Austin, Texas 78712 (512) 471-1534 FTS 729-4011 (Operator)
Utah	Ms. Genevieve Atwood Director (Genevieve)	Utah Geological & Mineral Survey 606 Black Hawk Way Salt Lake City, Utah 84108 (801) 581-6831 FTS Direct
Vermont	Dr. Charles A. Ratte State Geologist (Chuck)	State Office Building Agency of Environmental Conservation Montpelier, Vermont 05602 (802) 828-3365 FTS Direct
Virginia	Dr. Robert C. Milici State Geologist (Bob)	Virginia Division of Mineral Resources P.O. Box 3667 Charlottesville, Virginia 22903 (804) 293-5121 FTS 937-6011 (Operator)
Washington	Mr. Raymond Lasmanis State Geologist & Supervisor	Division of Geology & Earth Resources Department of Natural Resources Olympia, Washington 98504 (206) 459-6372 FTS Direct
West Virginia	Dr. Robert B. Erwin Director & State Geologist (Bob)	West Virginia Geological & Economic Survey P.O. Box 879 Morgantown, West Virginia 26507 (304) 594-2331 FTS 923-1511 (Operator)
Wisconsin	Dr. Meredith E. Ostrom State Geologist & Director (Buzz)	Wisconsin Geological & Natural History Survey University of Wisconsin Extension 1815 University Avenue Madison, Wisconsin 53705 (608) 262-1705 FTS Direct

Table F-2. (Continued)

State	Name & Title	Address & Telephone No.
Wyoming	Mr. Gary B. Glass State Geologist & Executive Director (Gary)	Geological Survey of Wyoming P.O. Box 3008 University Station Laramie, Wyoming 82071 (307) 742-2054, 766-2286 FTS 328-1110 (Operator)
Puerto Rico	Mr. Ramon M. Alonzo	Servicio Geologico de Puerto Rico Dept. de Recursos Naturales Apartado 5887 Puerta de Tierra San Juan, Puerto Rico 00906 (809) 723-2716

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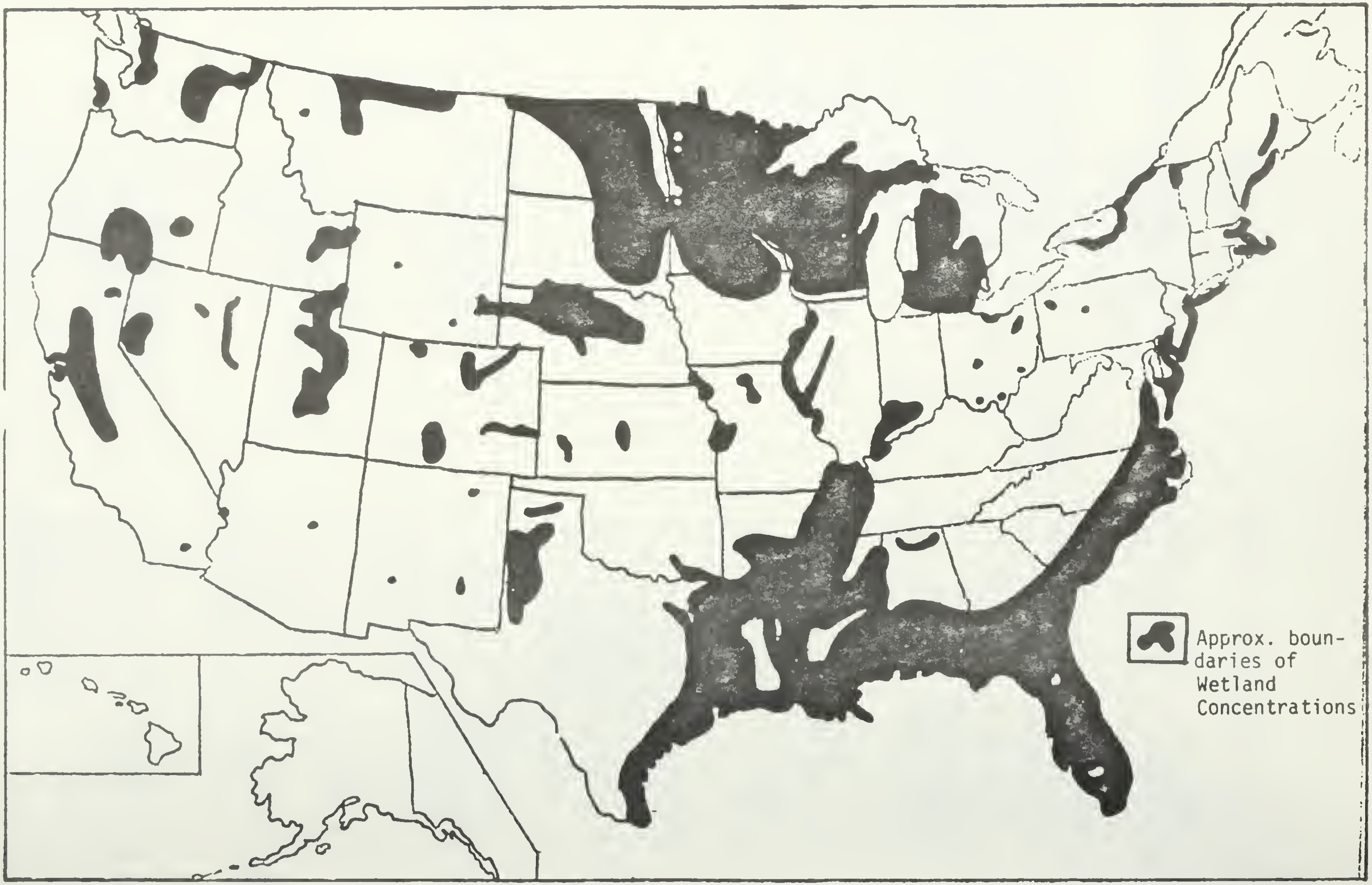
[a] Provided by the U.S. Geological Survey, Reston, Virginia.

Figure F-1. Concentration of Wetlands in the U.S.



Source: USEPA 1980f.

APPENDIX G

AUXILIARY INFORMATION ON SURFACE IMPOUNDMENTS

Table G-1. Relation Between Surface Impoundment Assessment (SIA) Rating and Raw Data[a]

Step 1. Rating of the Unsaturated Zone.

GUIDELINES FOR DETERMINING CATEGORY

Earth Material Category	I	II	III	IV	V	VI
Unconsolidated Rock	Gravel, Medium to Coarse Sand	Fine to Very Fine Sand	Sand with $<15\%$ clay, Silt	Sand with $>15\%$ but $\leq 50\%$ clay	Clay with $<50\%$ sand	Clay
Consolidated Rock	Cavernous or Fractured Limestone, Evaporites, Basalt Lava Fault Zones	Fractured Igneous and Metamorphic (Except Lava) Sandstone (Poorly Cemented)	Sandstone (Moderately Cemented) Fractured Shale	Sandstone (Well Cemented)	Siltstone	Unfractured Shale, Igneous and Metamorphic Rocks
Representative Permeability in gpd/ft^2 - in cm/sec -	 >200 $>10^{-2}$	 $2 - 200$ $10^{-4} - 10^{-2}$	 $0.2 - 2$ $10^{-5} - 10^{-4}$	 <0.2 $<10^{-5}$	 <0.02 $<10^{-6}$	 <0.002 $<10^{-7}$
RATING MATRIX						
Thickness of the Unsaturated Zone (in Meters) >30	9A	6B	4C	2D	0E	0F
$>10 \leq 30$	9B	7B	5C	3D	1E	0G
$>3 \leq 10$	9C	8B	6C	4D	2E	0H
$>1 \leq 3$	9D	9F	7C	5D	3E	1F
$>0 \leq 1$	9E	9G	9H	9I	9J	9K

Table G-1. (Continued)

Step 2. Rating of the Ground Water Availability

	Earth Material Category	I	II	III
GUIDELINES FOR DETERMINING CATEGORY	Unconsolidated Rock	Gravel or sand	Sand with ≤50% clay	Clay with <50% sand
	Consolidated Rock	Cavernous or Fractured Rock, Poorly Cemented Sandstone, Fault Zones	Moderately to Well Cemented Sandstone, Fractured Shale	Siltstone, Unfractured Shale and other Impervious Rock
	Representative Permeability in gpd/ft^2 in cm/sec	 > 2 $> 10^{-4}$	 $0.02 - 2$ 10^{-6} 10^{-4}	 < 0.02 $< 10^{-6}$
	RATING MATRIX			
	Thickness of Saturated Zone (Meters) ≥30	6A	4C	2E
	3-30	5A	3C	1E
	≤3	3A	1C	0E

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[a] This table is provided so that the user will understand the relationship between SIA ratings (available in the SIA data base) and key earth material parameters. See text (Section 5) and Silka and Swearingen 1978, for more information.

Source: Silka and Swearingen 1978.

Table G-2. Relation Between SIA Earth Material Categories and the Unified Soil Classification System

Step 1 Earth Material Category (and Step 1 Designation)	Unified Soil Classification System Designation	Permeability Range (cm/sec)
Gravel (I)	GW, GP	Permeable $> 10^{-4}$ cm/sec
Medium to Coarse Sand (I)	SW, SP	
Fine to Very Fine Sand (II)	SW, SP	
Sand with $\leq$15% Clay, Silt (III)	GM, SM, SC	Semi-permeable
Sand with $>$15% but $\leq$50% Clay (IV)	GM, SM, ML	10^{-2} to 10^{-6} cm/sec
Clay with $<$50% Sand (V)	OL, MH	Relatively impermeable
Clay (VI)	CL, CH, OH	$< 10^{-6}$ cm/sec

[a] This table is provided so that the user will understand the relationship between SIA ratings (available in the SIA data base) and key earth material parameters. See text (Section 5) and Silka and Swearingen 1978, for more information.

Source: Silka and Swearingen 1978.

APPENDIX H

AUXILIARY INFORMATION ON POTWS

Exhibit H-1. Needs Survey

This survey is conducted annually by the Priority Needs Branch of the Office of Water Program Operations of EPA in order to comply with the provisions of Section 205(a) and 516(b)(2) of the Clean Water Act of 1977. This survey collects design and operating characteristics for all of the municipal sewage treatment facilities in the nation and stores the data in computer retrievable form. The following characteristics are available for each facility:

- Scope of collection and treatment (e.g., wastewater collection only; wastewater collection, treatment, and sludge treatment onsite; handling, treatment, and disposal of sludge generated by other facilitates).
- Resident and nonresident population served and population not receiving treatment.
- Actual and designed daily flow (thousands of cubic meters per day).
- Average daily domestic flow and average daily industrial flow.
- Level of treatment (preliminary, primary, secondary, etc.).
- Treatment and disposal methods of the liquid line (e.g., trickling filter, land treatment of primary effluent, activated carbon). See Table H-8 in Appendix H for a list of all treatment parameters in the data base.
- Treatment and disposal methods of the sludge line (e.g., aerobic digestion, compositing, incineration - multiple hearth, landfill). See Table H-8 for a list of all treatment parameters in the data base.

Data may be retrieved from the Needs Survey data base for all facilities in a given state, county, congressional district, Standard Metropolitan Statistical Area (SMSA), zip code, or sewage authority jurisdiction. The choice of geographic designators in an exposure assessment will depend on how detailed and accurate the study must be. In most retrievals, all of the bulleted parameters are desirable because they are important pieces of information for Stages III, IV, and V. One carefully planned retrieval can provide data for all three stages in one step. There is no user's manual for this system, but the EPA staff in charge of Needs Survey retrievals has many program already written, several of which would serve the purpose of exposure assessments with little or no revision.

For more details on the Needs Survey data base, see the latest annual technical report available from the EPA Office of Water Program Operations (Washington, D.C.).

Exhibit H-2. Industrial Facility Discharge File (IFD)

This data base is maintained by the Monitoring and Data Support Division (MDSD) of the Office of Water Regulations and Standards. The IFD file is useful in estimating exposure from chemical substances in wastewater because it provides information on the industrial contributors to a given POTW. For each POTW, this data base will give the following for each industrial contributor belonging to one of the 21 major industrial categories listed in Table D-8:

- NPDES number, if any
- Facility name
- SIC codes (two most important codes)
- Type of discharge
- Flow (thousands of gallons per day).

The data for all POTWs in a state, county, or river basin can be retrieved by requesting SIC Code 4952 (which pertains to POTWs). This type of retrieval can be a source of both site-specific and generic data. It may be useful in determining whether a new industrial plant might discharge to a local POTW because it can verify whether the POTWs in the area accept industrial waste. Because a comprehensive list of all contributing wastewaters can be obtained in this way for a particular POTW, this data base in the prime candidate for use in conjunction with a POTW model for exposure assessments. This data base in currently used as input to the POTW model used by the MDSD (see Section 6.1).

Another useful retrieval from the IFD file is by SIC code of the industry of interest or for the geographic area of interest. For each existing industrial plant, this retrieval will give the following:

- NPDES permit number of each receiving POTW
- Total indirect flow (thousands of gallons per day)
- Indirect discharge type.

These data will allow a direct estimate of wastewaters routed to individual POTWs where site-specific information is desirable for existing industrial plants. This retrieval will also be useful in situations where the investigator is confronted with the problem of trying to guess whether any effluent from a new industrial plant will be routed to a local POTW, because a general picture of the current wastewater disposal practices of the industry (and for the geographic area) can be obtained from the printout.

The one drawback of the IFD data base is that it is only about 75 to 80% complete. Therefore, it may not include all of the POTWs or industrial plants of interest in a given exposure assessment.

Table H-1. Occurrence of Priority Pollutants in POTW Influents: Part 1 - Plants 1 to 40a,b

PARAMETER	NUMBER OF SAMPLES ANALYZED	NUMBER OF TIMES DETECTED	PERCENT OF SAMPLES WHERE DETECTED	UNITS	MINIMUM VALUE DETECTED	MAXIMUM VALUE
ZINC	282	282	100	UG/L	22	9250
CYANIDE	284	283	100	UG/L	3	7580
COPPER	282	281	100	UG/L	7	2300
TOLUENE	288	276	96	UG/L	1	13000
CHROMIUM	282	268	95	UG/L	8	2380
TETRACHLOROETHYLENE	288	273	95	UG/L	1	5700
METHYLENE CHLORIDE	288	266	92	UG/L	1	49000
BIS(2-ETHYLHEXYL) PHTHALATE	287	265	92	UG/L	2	670
CHLOROFORM	288	263	91	UG/L	1	430
TRICHLOROETHYLENE	288	260	90	UG/L	1	1800
1,1,1-TRICHLOROETHANE	288	244	85	UG/L	1	30000
ETHYLBENZENE	288	231	80	UG/L	1	730
NICKEL	282	224	79	UG/L	5	5970
PHENOL	288	228	79	UG/L	1	1400
SILVER	282	200	71	UG/L	2	320
MERCURY	282	196	70	NG/L	200	4000
DI-N-BUTYL PHTHALATE	287	185	64	UG/L	1	140
LEAD	282	176	62	UG/L	16	2540
1,2-TRANS-DICHLOROETHYLENE	288	179	62	UG/L	1	200
BENZENE	288	175	61	UG/L	1	1560
BUTYL BENZYL PHTHALATE	287	165	57	UG/L	2	560
CADMIUM	282	157	56	UG/L	1	1800
DIETHYL PHTHALATE	287	151	53	UG/L	1	42
NAPHTHALENE	287	142	49	UG/L	1	150
1,1-DICHLOROETHANE	288	89	31	UG/L	1	24
PENTACHLOROPHENOL	287	84	29	UG/L	1	640
GAMMA-BHC	288	75	26	NG/L	20	3900
1,1-DICHLOROETHYLENE	288	74	26	UG/L	1	243
1,2-DICHLOROBENZENE	287	67	23	UG/L	1	440
PHENANTHRENE	287	57	20	UG/L	1	93
ANTHRACENE	287	52	18	UG/L	1	93
1,4-DICHLOROBENZENE	287	49	17	UG/L	2	200
ARSENIC	282	43	15	UG/L	2	80
1,2-DICHLOROETHANE	288	42	15	UG/L	1	76000
ANTIMONY	282	39	14	UG/L	1	192
CHLOROBENZENE	288	36	13	UG/L	1	1500
DIMETHYL PHTHALATE	287	33	11	UG/L	1	110
METHYL CHLORIDE	288	33	11	UG/L	1	1900
1,2,4-TRICHLOROBENZENE	287	28	10	UG/L	3	4300
2,4-DIMETHYLPHENOL	288	28	10	UG/L	1	55
CARBON TETRACHLORIDE	288	25	9	UG/L	1	1900
TRICHLOROFLUOROMETHANE	288	25	9	UG/L	1	190
SELENIUM	282	24	9	UG/L	1	10
DICHLOROBROMOMETHANE	288	24	8	UG/L	1	22
ALPHA-BHC	288	22	8	NG/L	20	4400
1,1,2-TRICHLOROETHANE	288	21	7	UG/L	1	135
1,2-DICHLOROPROPANE	288	21	7	UG/L	1	2600
DI-N-OCTYL PHTHALATE	287	20	7	UG/L	2	210
FLUORANTHENE	287	20	7	UG/L	1	5

Table H-1. (Part 1 - continued)

PARAMETER	NUMBER OF SAMPLES ANALYZED	NUMBER OF TIMES DETECTED	PERCENT OF SAMPLES WHERE DETECTED	UNITS	MINIMUM VALUE DETECTED	MAXIMUM VALUE
2,4-DICHLOROPHENOL	288	20	7	UG/L	1	25
PYRENE	287	19	7	UG/L	1	84
1,3-DICHLOROBENZENE	287	19	7	UG/L	2	270
1,1,2,2-TETRACHLOROETHANE	288	19	7	UG/L	1	52
VINYL CHLORIDE	288	17	6	UG/L	28	3900
HEPTACHLOR	288	15	5	NG/L	80	500
PCB-1242	288	13	5	NG/L	2300	49600
2,4,6-TRICHLOROPHENOL	288	13	5	UG/L	1	11
FLUORENE	287	11	4	UG/L	1	5
METHYL BROMIDE	288	10	3	UG/L	18	164
BERYLLIUM	282	9	3	UG/L	1	4
ACENAPHTHENE	287	9	3	UG/L	1	21
CHRYSENE	287	9	3	UG/L	1	15
1,2-BENZANTHRACENE	287	9	3	UG/L	1	15
DELTA-BHC	288	9	3	NG/L	100	1400
PARACHLOROMETA CRESOL	288	9	3	UG/L	1	41
2-CHLOROPHENOL	288	9	3	UG/L	1	5
THALLIUM	282	8	3	UG/L	1	19
CHLORODIBROMOMETHANE	288	8	3	UG/L	1	3
BROMOFORM	288	7	2	UG/L	1	81
DICHLORODIFLUOROMETHANE	288	7	2	UG/L	42	1000
1,3-DICHLOROPROPYLENE	288	7	2	UG/L	2	100
ISOPHORONE	287	5	2	UG/L	5	23
N-NITROSODIPHENYLAMINE	287	5	2	UG/L	1	14
HEXACHLOROBENZENE	287	4	1	UG/L	1	20
1,2-DIPHENYLHYDRAZINE	287	4	1	UG/L	1	50
ALDRIN	289	4	1	NG/L	30	5000
INDENO(1,2,3-C,D) PYRENE	280	3	1	UG/L	5	5
BENZO (A)PYRENE	284	3	1	UG/L	5	10
2,4-DINITROTOLUENE	287	3	1	UG/L	2	8
ALPHA-ENDOSULFAN	288	3	1	NG/L	470	2700
CHLOROETHANE	288	3	1	UG/L	3	38
PCB-1254	288	3	1	NG/L	450	5500
BIS(2-CHLOROETHYOXY) METHANE	276	2	1	UG/L	5	5
1,12-BENZOPERYLENE	280	2	1	UG/L	5	35
1,2:5,6-DIBENZANTHRACENE	280	2	1	UG/L	5	5
3,4-BENZOFLUORANTHENE	285	2	1	UG/L	5	5
11,12-BENZOFLUORANTHENE	286	2	1	UG/L	5	5
HEXACHLOROETHANE	287	2	1	UG/L	6	12
2-CHLORONAPHTHALENE	287	2	1	UG/L	3	7
4,4'-DDD	287	2	1	NG/L	310	770
BETA-BHC	288	2	1	NG/L	10	1000
DIELDRIN	288	2	1	NG/L	30	40
HEPTACHLOR EPOXIDE	288	2	1	NG/L	230	500
ACENAPHTHYLENE	287	1	LT 1	UG/L	5	5
HEXACHLOROBUTADIENE	287	1	LT 1	UG/L	5	5
2,6-DINITROTOLUENE	287	1	LT 1	UG/L	5	5
4-BROMOPHENYL PHENYL ETHER	287	1	LT 1	UG/L	5	5
ACRYLONITRILE	288	1	LT 1	UG/L	82	82

Table H-1. (Part 1 - continued)

PARAMETER	NUMBER OF SAMPLES ANALYZED	NUMBER OF TIMES DETECTED	PERCENT OF SAMPLES WHERE DETECTED	UNITS	MINIMUM VALUE DETECTED	MAXIMUM VALUE
2-CHLOROETHYL VINYL ETHER	288	1	LT 1	UG/L	10	10
2-NITROPHENOL	288	1	LT 1	UG/L	64	64
2,4-DINITROPHENOL	288	1	LT 1	UG/L	7	7
4,4'-DDT	288	1	LT 1	NG/L	1200	1200

[a] Based on a study in which a total of 50 POTWs were sampled for priority pollutants. Results were reported for two groups of POTWs, comprising 40 plants and 10 plants, respectively. Consult Burns and Roe 1982 for results of sampling at individual plants.

[b] Pollutants not listed were never detected.
Occurrences are based on all influent samples taken.
Pollutants reported as less than the detection limit
and unconfirmed pesticides are assumed not detected.

Source: Burns and Roe 1982.

Table H-1. Occurrence of Priority Pollutants in POTW Influents: Part 2 - Supplemental Plants 51 to 60^{a,b}

PARAMETER	NUMBER OF SAMPLES ANALYZED	NUMBER OF TIMES DETECTED	PERCENT OF SAMPLES WHERE DETECTED	UNITS	MINIMUM VALUE DETECTED	MAXIMUM VALUE
COPPER	60	60	100	UG/L	11	1090
ZINC	60	60	100	UG/L	62	9000
BIS(2-ETHYLHEXYL) PHTHALATE	60	59	98	UG/L	1	1610
SILVER	60	58	97	UG/L	1	80
TOLUENE	60	57	95	UG/L	1	2100
CHROMIUM	60	56	93	UG/L	3	6950
NICKEL	60	54	90	UG/L	6	559
TETRACHLOROETHYLENE	60	54	90	UG/L	1	1250
METHYLENE CHLORIDE	60	53	88	UG/L	1	125
DI-N-BUTYL PHTHALATE	60	48	80	UG/L	1	200
CHLOROFORM	60	46	77	UG/L	1	1100
MERCURY	60	45	75	NG/L	100	7000
1,1,1-TRICHLOROETHANE	60	45	75	UG/L	1	1800
BENZENE	60	43	72	UG/L	1	230
PHENOL	60	43	72	UG/L	2	1200
ETHYLBENZENE	60	41	68	UG/L	1	135
TRICHLOROETHYLENE	60	41	68	UG/L	1	500
CYANIDE	58	39	67	UG/L	10	340
DIETHYL PHTHALATE	60	39	65	UG/L	1	24
1,2-TRANS-DICHLOROETHYLENE	60	39	65	UG/L	1	98
LEAD	60	37	62	UG/L	50	1400
ARSENIC	60	34	57	UG/L	1	64
ANTIMONY	60	25	42	UG/L	1	122
NAPHTHALENE	60	23	38	UG/L	1	380
CADMIUM	60	21	35	UG/L	3	1370
SELENIUM	60	21	35	UG/L	1	10
CHLOROETHANE	60	17	28	UG/L	15	1600
DI-N-OCTYL PHTHALATE	60	15	25	UG/L	2	90
1,2-DICHLOROBENZENE	60	14	23	UG/L	1	350
BUTYL BENZYL PHTHALATE	60	13	22	UG/L	1	110
PYRENE	60	13	22	UG/L	1	25
ACENAPHTHENE	60	12	20	UG/L	6	1950
FLUORANTHENE	60	12	20	UG/L	2	57
ANTHRACENE	60	11	18	UG/L	1	424
PHENANTHRENE	60	11	18	UG/L	1	369
1,1-DICHLOROETHYLENE	60	10	17	UG/L	1	29
CHLOROBENZENE	60	9	15	UG/L	1	10
METHYL CHLORIDE	60	9	15	UG/L	10	460
1,1-DICHLOROETHANE	60	9	15	UG/L	1	87
2,4-DIMETHYLPHENOL	60	9	15	UG/L	3	56
GAMMA-BHC	60	8	13	NG/L	400	500
VINYL CHLORIDE	60	8	13	UG/L	6	70000
1,2-DICHLOROETHANE	60	7	12	UG/L	3	13000
1,4-DICHLOROBENZENE	60	7	12	UG/L	4	60
BIS(2-CHLOROETHYOXY) METHANE	60	6	10	UG/L	1	35
CHRYSENE	60	6	10	UG/L	2	8
DIMETHYL PHTHALATE	60	6	10	UG/L	4	34
FLUORENE	60	6	10	UG/L	6	62
1,2-BENZANTHRACENE	60	6	10	UG/L	2	16

Table H-1. (Part 2 - continued)

PARAMETER	NUMBER OF SAMPLES ANALYZED	NUMBER OF TIMES DETECTED	PERCENT OF SAMPLES WHERE DETECTED	UNITS	MINIMUM VALUE DETECTED	MAXIMUM VALUE
1,2-DIPHENYLHYDRAZINE	60	6	10	UG/L	2	6
1,2,4-TRICHLOROBENZENE	60	6	10	UG/L	54	4600
THALLIUM	61	6	10	UG/L	1	10
PENTACHLOROPHENOL	60	5	8	UG/L	1	53
3,3'-DICHLOROBENZIDINE	60	5	8	UG/L	19	209
NITROBENZENE	60	4	7	UG/L	15	220
2,4-DICHLOROPHENOL	60	4	7	UG/L	108	1190
DELTA-BHC	60	3	5	NG/L	800	3500
2,4,6-TRICHLOROPHENOL	60	3	5	UG/L	4	12
ACENAPHTHYLENE	60	2	3	UG/L	1	2
ALDRIN	60	2	3	NG/L	100	1800
ALPHA-BHC	60	2	3	NG/L	500	500
CARBON TETRACHLORIDE	60	2	3	UG/L	1	2
2-CHLOROPHENOL	60	2	3	UG/L	39	108
2,4-DINITROTOLUENE	60	2	3	UG/L	13	18
2,6-DINITROTOLUENE	60	2	3	UG/L	20	25
4-NITROPHENOL	60	2	3	UG/L	470	550
BIS(2-CHLOROETHYL) ETHER	60	1	2	UG/L	748	748
HEPTACHLOR EPOXIDE	60	1	2	NG/L	900	900
HEXACHLOROBENZENE	60	1	2	UG/L	10	10
ISOPHORONE	60	1	2	UG/L	2	2
PARACHLOROMETA CRESOL	60	1	2	UG/L	4	4
TRICHLOROFLUOROMETHANE	60	1	2	UG/L	1	1
1,2-DICHLOROPROPANE	60	1	2	UG/L	88	88
1,3-DICHLOROBENZENE	60	1	2	UG/L	1	1
2,4-DINITROPHENOL	60	1	2	UG/L	35	35
4,4'-DDE	60	1	2	NG/L	400	400

[a] Based on a study in which a total of 50 POTWs were sampled for priority pollutants. Results were reported for two groups of POTWs, comprising 40 plants and 10 plants, respectively. Consult Burns and Roe 1982 for results of sampling at individual plants.

[b] Pollutants not listed were never detected. Occurrences are based on all influent samples taken. Pollutants reported as less than the detection limit and unconfirmed pesticides are assumed not detected.

Table H-2. Summary of Selected Influent Pollutant Concentrations for POTWs 1 through 40[a]

Parameter [b]	Average of Plant Average Concentrations	Median of Plant Average Concentrations	Flow Weighted Average of Plant Average Concentrations
BOD (mg/l)	214	215	218
TSS (mg/l)	182	153	201
Cadmium	38	3	17
Chromium	173	105	142
Copper	226	132	251
Cyanide	577	249	420
Lead	101	53	119
Mercury (ng/l)	551	517	573
Nickel	120	54	82
Silver	9	8	9
Zinc	723	273	740
Benzene	20	2	18
1,1,1-Trichloroethane	220	29	343
Chloroform	17	7	18
1,2-trans-Dichloroethylene	7	2	4
Ethylbenzene	22	8	32
Methylene Chloride	508	38	246
Tetrachloroethylene	125	23	188
Toluene	216	27	289
Trichloroethylene	76	28	86
Phenol	54	7	70
Naphthalene	7	3	8
Bis (2-ethyl hexyl) Phthalate	45	27	51
Butyl Benzyl Phthalate	12	3	16
Di-N-Butyl Phthlate	9	4	10
Diethyl Phthalate	4	3	3
Total Metals [c]	1398	709	1367
Total Volatiles	1899	277	1793
Total Acids	69	13	76
Total Base Neutrals	117	71	109

[a] Based on a study in which a total of 50 POTWs were sampled for priority pollutants. Results were reported for two groups of POTWs, comprising 40 plants and 10 plants, respectively. Consult Burns and Roe 1982 for results of sampling at individual plants.

[b] All units in ug/l unless otherwise noted.

[c] Excluding Cyanide.

Source: Burns and Roe 1982.

Table H-3. Occurrence of Priority Pollutants in POTW Effluents: Part 1- Plants 1 to 40a,b

PARAMETER	NUMBER OF SAMPLES ANALYZED	NUMBER OF TIMES DETECTED	PERCENT OF SAMPLES WHERE DETECTED	UNITS	MINIMUM VALUE DETECTED	MAXIMUM VALUE
CYANIDE	276	268	97	UG/L	2	2140
ZINC	289	272	94	UG/L	18	3150
COPPER	289	263	91	UG/L	3	255
METHYLENE CHLORIDE	302	260	86	UG/L	1	62000
CHROMIUM	289	247	85	UG/L	2	759
BIS(2-ETHYLHEXYL) PHTHALATE	302	254	84	UG/L	1	370
CHLOROFORM	302	247	82	UG/L	1	87
TETRACHLOROETHYLENE	302	239	79	UG/L	1	1200
NICKEL	289	216	75	UG/L	7	679
TOLUENE	302	160	53	UG/L	1	1100
DI-N-BUTYL PHTHALATE	302	158	52	UG/L	1	97
1,1,1-TRICHLOROETHANE	302	157	52	UG/L	1	3500
TRICHLOROETHYLENE	302	137	45	UG/L	1	230
GAMMA-BHC	303	99	33	NG/L	10	1400
MERCURY	288	88	31	NG/L	200	1200
PHENOL	302	87	29	UG/L	1	89
CADMIUM	289	81	28	UG/L	2	82
SILVER	289	73	25	UG/L	1	30
ETHYLBENZENE	302	73	24	UG/L	1	49
BENZENE	302	69	23	UG/L	1	72
LEAD	289	61	21	UG/L	20	217
PENTACHLOROPHENOL	301	63	21	UG/L	1	440
DICHLOROBROMOMETHANE	302	47	16	UG/L	1	6
DIETHYL PHTHALATE	301	39	13	UG/L	1	7
1,2-TRANS-DICHLOROETHYLENE	302	39	13	UG/L	1	17
ANTIMONY	289	37	13	UG/L	1	69
ARSENIC	289	35	12	UG/L	1	72
BUTYL BENZYL PHTHALATE	302	34	11	UG/L	1	34
SELENIUM	289	29	10	UG/L	1	150
1,1-DICHLOROETHYLENE	302	29	10	UG/L	1	11
CHLORODIBROMOMETHANE	302	25	8	UG/L	1	5
1,2-DICHLOROBENZENE	302	24	8	UG/L	1	27
1,2-DICHLOROETHANE	302	24	8	UG/L	1	13000
1,1-DICHLOROETHANE	302	23	8	UG/L	1	6
ALPHA-BHC	303	23	8	NG/L	20	740
METHYL CHLORIDE	302	21	7	UG/L	2	540
CARBON TETRACHLORIDE	302	19	6	UG/L	1	67
NAPHTHALENE	302	17	6	UG/L	1	24
2,4-DICHLOROPHENOL	302	13	4	UG/L	1	3
1,2-DICHLOROPROPANE	302	12	4	UG/L	1	8
1,2,4-TRICHLOROBENZENE	302	12	4	UG/L	3	310
DI-N-OCTYL PHTHALATE	302	11	4	UG/L	5	13
TRICHLOROFLUOROMETHANE	302	11	4	UG/L	1	14
2,4-DIMETHYLPHENOL	302	11	4	UG/L	1	10
CHLOROBENZENE	302	10	3	UG/L	1	9
PHENANTHRENE	302	10	3	UG/L	1	32
ANTHRACENE	302	9	3	UG/L	1	32
BROMOFORM	302	9	3	UG/L	1	5
2,4,6-TRICHLOROPHENOL	302	9	3	UG/L	1	3

Table H-3. (Part 1 - continued)

PARAMETER	NUMBER OF SAMPLES ANALYZED	NUMBER OF TIMES DETECTED	PERCENT OF SAMPLES WHERE DETECTED	UNITS	MINIMUM VALUE DETECTED	MAXIMUM VALUE
1,1,2-TRICHLOROETHANE	302	8	3	UG/L	1	6
1,1,2,2-TETRACHLOROETHANE	302	8	3	UG/L	1	5
1,4-DICHLOROBENZENE	302	8	3	UG/L	3	9
2-NITROPHENOL	302	8	3	UG/L	5	14
ALDRIN	303	8	3	NG/L	1000	6000
DELTA-BHC	303	8	3	NG/L	20	1300
CHRYSENE	302	7	2	UG/L	1	11
DIMETHYL PHTHALATE	302	7	2	UG/L	1	5
VINYL CHLORIDE	302	7	2	UG/L	2	200
1,2-BENZANTHRACENE	302	7	2	UG/L	1	11
1,3-DICHLOROBENZENE	302	7	2	UG/L	5	5
BETA-BHC	303	7	2	NG/L	40	1700
THALLIUM	289	6	2	UG/L	1	2
ACENAPHTHENE	302	6	2	UG/L	1	7
HEPTACHLOR	303	6	2	NG/L	30	1500
HEPTACHLOR EPOXIDE	303	6	2	NG/L	90	500
4-NITROPHENOL	302	5	2	UG/L	5	220
BERYLLIUM	289	4	1	UG/L	1	12
METHYL BROMIDE	302	4	1	UG/L	31	220
PYRENE	302	4	1	UG/L	5	5
PCB-1242	303	4	1	NG/L	750	2600
ACENAPHTHYLENE	302	3	1	UG/L	5	5
FLUORANTHENE	302	3	1	UG/L	5	5
HEXACHLOROBENZENE	302	3	1	UG/L	1	10
ISOPHORONE	302	3	1	UG/L	1	12
PARACHLOROMETA CRESOL	302	3	1	UG/L	1	4
4,4'-DDD	303	3	1	NG/L	60	300
INDENO(1,2,3-C,D) PYRENE	296	2	1	UG/L	4	5
DICHLORODIFLUOROMETHANE	302	2	1	UG/L	58	58
FLUORENE	302	2	1	UG/L	1	5
2-CHLOROPHENOL	302	2	1	UG/L	1	5
2,4-DINITROTOLUENE	302	2	1	UG/L	1	2
3,3'-DICHLOROBENZIDINE	302	2	1	UG/L	5	5
1,12-BENZOPERYLENE	295	1	LT 1	UG/L	4	4
1,2:5,6-DIBENZANTHRACENE	296	1	LT 1	UG/L	5	5
4,6-DINITRO-O-CRESOL	301	1	LT 1	UG/L	2	2
CHLOROETHANE	302	1	LT 1	UG/L	5	5
1,2-DIPHENYLHYDRAZINE	302	1	LT 1	UG/L	2	2
CHLORDANE	303	1	LT 1	NG/L	200	200
DIELDRIN	303	1	LT 1	NG/L	40	40
PCB-1254	303	1	LT 1	NG/L	500	500

[a] Based on a study in which a total of 50 POTWs were sampled for priority pollutants. Results were reported for two groups of POTWs, comprising 40 plants and 10 plants, respectively. Consult Burns and Roe 1982 for results of sampling at individual plants.

[b] Pollutants not listed were never detected.
Occurrences are based on all influent samples taken.
Pollutants reported as less than the detection limit and unconfirmed pesticides are assumed not detected.

Source: Burns and Roe 1982.

Table H-3. Occurrence of Priority Pollutants in POTW Effluents: Part 2 - Supplemental Plants 51 to 60[a,b]

PARAMETER	NUMBER OF SAMPLES ANALYZED	NUMBER OF TIMES DETECTED	PERCENT OF SAMPLES WHERE DETECTED	UNITS	MINIMUM VALUE DETECTED	MAXIMUM VALUE
BIS(2-ETHYLHEXYL) PHTHALATE	60	57	95	UG/L	1	418
ZINC	60	57	95	UG/L	11	3800
METHYLENE CHLORIDE	60	52	87	UG/L	1	135
NICKEL	60	51	85	UG/L	5	351
CHROMIUM	60	50	83	UG/L	3	890
COPPER	60	49	82	UG/L	4	169
DI-N-BUTYL PHTHALATE	60	47	78	UG/L	1	138
CHLOROFORM	60	38	63	UG/L	1	106
CYANIDE	59	33	56	UG/L	10	400
SILVER	59	30	51	UG/L	1	44
ARSENIC	60	30	50	UG/L	1	122
DIETHYL PHTHALATE	60	26	43	UG/L	1	32
1,1,1-TRICHLOROETHANE	60	26	43	UG/L	1	70
TOLUENE	60	24	40	UG/L	1	140
SELENIUM	59	22	37	UG/L	1	1045
ANTIMONY	60	22	37	UG/L	1	30
TRICHLOROETHYLENE	60	19	32	UG/L	2	630
LEAD	60	17	28	UG/L	40	400
TETRACHLOROETHYLENE	60	17	28	UG/L	1	200
PHENOL	60	16	27	UG/L	1	35
CHLOROETHANE	60	15	25	UG/L	100	960
CADMIUM	60	14	23	UG/L	1	199
DI-N-OCTYL PHTHALATE	60	12	20	UG/L	1	12
1,2-TRANS-DICHLOROETHYLENE	60	12	20	UG/L	1	5
MERCURY	60	10	17	NG/L	100	2000
BENZENE	60	9	15	UG/L	1	53
ETHYLBENZENE	60	8	13	UG/L	1	120
ACENAPHTHENE	60	7	12	UG/L	1	25
BUTYL BENZYL PHTHALATE	60	6	10	UG/L	1	2200
FLUORANTHENE	60	6	10	UG/L	7	33
METHYL CHLORIDE	60	6	10	UG/L	5	335
PYRENE	60	6	10	UG/L	2	11
VINYL CHLORIDE	60	6	10	UG/L	2300	5800
THALLIUM	59	5	8	UG/L	1	9
GAMMA-BHC	60	5	8	NG/L	500	500
1,2,4-TRICHLOROBENZENE	60	5	8	UG/L	2	10
1,2-DICHLOROBENZENE	60	4	7	UG/L	1	6
1,2-DIPHENYLHYDRAZINE	60	4	7	UG/L	1	1
HEPTACHLOR	60	3	5	NG/L	500	500
ISOPHORONE	60	3	5	UG/L	2	8
2,4-DICHLOROPHENOL	60	3	5	UG/L	209	470
2,4-DIMETHYLPHENOL	60	3	5	UG/L	1	1
ALPHA-BHC	60	2	3	NG/L	200	600
CHLOROBENZENE	60	2	3	UG/L	2	2
DELTA-BHC	60	2	3	NG/L	300	500
4,6-DINITRO-O-CRESOL	60	2	3	UG/L	1	4
ALDRIN	60	1	2	NG/L	100	100
ALPHA-ENDOSULFAN	60	1	2	NG/L	1333	1333

Table H-3. (Part 2 - continued)

PARAMETER	NUMBER OF SAMPLES ANALYZED	NUMBER OF TIMES DETECTED	PERCENT OF SAMPLES WHERE DETECTED	UNITS	MINIMUM VALUE DETECTED	MAXIMUM VALUE
ANTHRACENE	60	1	2	UG/L	4	4
BETA-BHC	60	1	2	NG/L	500	500
BETA-ENDOSULFAN	60	1	2	NG/L	680	680
DIMETHYL PHTHALATE	60	1	2	UG/L	2	2
FLUORENE	60	1	2	UG/L	3	3
HEPTACHLOR EPOXIDE	60	1	2	NG/L	200	200
INDENO(1,2,3-C,D) PYRENE	60	1	2	UG/L	42	42
NITROBENZENE	60	1	2	UG/L	4	4
PHENANTHRENE	60	1	2	UG/L	4	4
1,2-DICHLOROETHANE	60	1	2	UG/L	1	1
1,4-DICHLOROBENZENE	60	1	2	UG/L	4	4
2,4-DINITROTOLUENE	60	1	2	UG/L	7	7
4-CHLOROPHENYL PHENYL ETHER	60	1	2	UG/L	6	6
4,4'-DDT	60	1	2	NG/L	490	490

[a] Based on a study in which a total of 50 POTWs were sampled for priority pollutants. Results were reported for two groups of POTWs, comprising 40 plants and 10 plants, respectively. Consult Burns and Roe 1982 for results of sampling at individual plants.

[b] Pollutants not listed were never detected.
Occurrences are based on all influent samples taken.
Pollutants reported as less than the detection limit
and unconfirmed pesticides are assumed not detected.

Source: Burns and Roe 1982.

Table H-4. Occurrence of Priority Pollutants in POTW Raw Sludges: Part 1-Plants 1 to 40^{a,b}

PARAMETER	NUMBER OF SAMPLES ANALYZED	NUMBER OF TIMES DETECTED	PERCENT OF SAMPLES WHERE DETECTED	UNITS	MINIMUM VALUE DETECTED	MAXIMUM VALUE
CYANIDE	432	429	99	UG/L	36	286000
ZINC	439	434	99	UG/L	70	1100000
LEAD	438	432	99	UG/L	31	170000
COPPER	436	422	97	UG/L	100	180000
BIS(2-ETHYLHEXYL) PHTHALATE	437	415	95	UG/L	2	47000
TOLUENE	434	408	94	UG/L	1	427300
ARSENIC	438	407	93	UG/L	1	6000
CHROMIUM	438	407	93	UG/L	110	160000
SILVER	438	400	91	UG/L	15	24000
ANTIMONY	429	386	90	UG/L	1	2000
CADMIUM	438	381	87	UG/L	4	95000
NICKEL	438	364	83	UG/L	12	84000
SELENIUM	431	335	78	UG/L	1	140000
METHYLENE CHLORIDE	436	318	73	UG/L	1	10500
ETHYLBENZENE	436	275	63	UG/L	1	4200
MERCURY	435	267	61	NG/L	110	690000
BENZENE	436	264	61	UG/L	1	953
1,2-TRANS-DICHLOROETHYLENE	436	261	60	UG/L	1	96000
TRICHLOROETHYLENE	432	232	54	UG/L	1	32700
PYRENE	437	233	53	UG/L	1	1700
PHENANTHRENE	437	232	53	UG/L	1	10100
PHENOL	438	218	50	UG/L	5	17000
ANTHRACENE	437	210	48	UG/L	1	10100
DI-N-BUTYL PHTHALATE	437	195	45	UG/L	1	6900
FLUORANTHENE	437	194	44	UG/L	1	9930
BUTYL BENZYL PHTHALATE	437	187	43	UG/L	2	45000
TETRACHLOROETHYLENE	436	175	40	UG/L	1	2800
1,1-DICHLOROETHANE	436	150	34	UG/L	1	2885
NAPHTHALENE	437	149	34	UG/L	1	5200
CHRYSENE	436	136	31	UG/L	1	1500
1,2-BENZANTHRACENE	437	116	27	UG/L	1	1500
CHLOROFORM	436	104	24	UG/L	1	366
BERYLLIUM	439	98	22	UG/L	2	310
1,1,1-TRICHLOROETHANE	436	83	19	UG/L	1	10910
1,4-DICHLOROBENZENE	437	74	17	UG/L	2	12000
1,2-DICHLOROBENZENE	437	71	16	UG/L	3	1319
1,1,2,2-TETRACHLOROETHANE	434	66	15	UG/L	1	3040
PENTACHLOROPHENOL	438	62	14	UG/L	10	10500
CHLOROBENZENE	436	57	13	UG/L	1	687
1,2,4-TRICHLOROBENZENE	437	57	13	UG/L	2	8300
3,4-BENZOFLUORANTHENE	437	47	11	UG/L	1	2400
DI-N-OCTYL PHTHALATE	437	45	10	UG/L	4	1024
1,2-DICHLOROETHANE	436	44	10	UG/L	1	10010
DICHLORODIFLUOROMETHANE	436	40	9	UG/L	2	4300
1,3-DICHLOROBENZENE	437	40	9	UG/L	14	1900
DIETHYL PHTHALATE	437	39	9	UG/L	1	786
11,12-BENZOFLUORANTHENE	438	37	8	UG/L	1	379
VINYL CHLORIDE	435	35	8	UG/L	8	62000
THALLIUM	437	32	7	UG/L	1	31

Table H-4. (Part 1 - continued)

PARAMETER	NUMBER OF SAMPLES ANALYZED	NUMBER OF TIMES DETECTED	PERCENT OF SAMPLES WHERE DETECTED	UNITS	MINIMUM VALUE DETECTED	MAXIMUM VALUE
CHLOROETHANE	436	31	7	UG/L	5	71000
1,2-DICHLOROPROPANE	435	28	6	UG/L	1	103
DICHLOROBROMOMETHANE	436	28	6	UG/L	3	260
FLUORENE	437	28	6	UG/L	1	1300
METHYL CHLORIDE	436	25	6	UG/L	12	6100
TRICHLOROFLUOROMETHANE	436	22	5	UG/L	2	113
ACENAPHTHENE	437	21	5	UG/L	6	4600
BENZO (A)PYRENE	437	21	5	UG/L	1	490
DIMETHYL PHTHALATE	437	20	5	UG/L	3	650
METHYL BROMIDE	431	19	4	UG/L	33	30000
1,1,2-TRICHLOROETHANE	434	16	4	UG/L	1	2100
CARBON TETRACHLORIDE	436	16	4	UG/L	5	3030
1,1-DICHLOROETHYLENE	436	14	3	UG/L	1	14000
CHLORODIBROMOMETHANE	435	10	2	UG/L	10	75
2-CHLOROPHENOL	438	9	2	UG/L	11	72
2,4-DICHLOROPHENOL	438	9	2	UG/L	14	298
INDENO(1,2,3-C,D) PYRENE	437	8	2	UG/L	17	102
1,12-BENZOPERYLENE	437	8	2	UG/L	12	133
HEXACHLOROBENZENE	437	7	2	UG/L	28	780
ACRYLONITRILE	436	5	1	UG/L	5	290
PARACHLOROMETA CRESOL	438	5	1	UG/L	12	35
ACENAPHTHYLENE	437	3	1	UG/L	24	320
1,3-DICHLOROPROPYLENE	436	2	LT 1	UG/L	5	19
1,215,6-DIBENZANTHRACENE	437	2	LT 1	UG/L	12	50
2,4,6-TRICHLOROPHENOL	438	2	LT 1	UG/L	11	16
BROMOFORM	436	1	LT 1	UG/L	5	5
HEXACHLOROBUTADIENE	437	1	LT 1	UG/L	2700	2700
2-CHLORONAPHTHALENE	437	1	LT 1	UG/L	1600	1600
4,4'-DDE	443	1	LT 1	NG/L	10000	10000

[a] Based on a study in which a total of 50 POTWs were sampled for priority pollutants. Results were reported for two groups of POTWs, comprising 40 plants and 10 plants, respectively. Consult Burns and Roe 1982 for results of sampling at individual plants.

[b] Pollutants not listed were never detected.
Occurrences are based on all influent samples taken.
Pollutants reported as less than the detection limit and unconfirmed pesticides are assumed not detected.

Source: Burns and Roe 1982.

Table H-4. Occurrence of Priority Pollutants in POTW Raw Sludges: Part 2 - Supplemental Plant 51 to 60[a,b]

PARAMETER	NUMBER OF SAMPLES ANALYZED	NUMBER OF TIMES DETECTED	PERCENT OF SAMPLES WHERE DETECTED	UNITS	MINIMUM VALUE DETECTED	MAXIMUM VALUE
BIS(2-ETHYLHEXYL) PHTHALATE	42	42	100	UG/L	440	47000
COPPER	78	78	100	UG/L	330	82472
LEAD	81	81	100	UG/L	180	82000
SILVER	81	81	100	UG/L	6	4500
TOLUENE	41	41	100	UG/L	2	9601970
ZINC	77	77	100	UG/L	840	5180000
NICKEL	79	78	99	UG/L	38	27300
MERCURY	81	78	96	NG/L	600	860000
CHROMIUM	80	77	96	UG/L	120	110000
ARSENIC	81	74	91	UG/L	1	5000
CADMIUM	81	68	84	UG/L	12	74100
ANTIMONY	81	65	80	UG/L	1	520
ETHYLBENZENE	41	30	73	UG/L	1	927
TRICHLOROETHYLENE	41	30	73	UG/L	2	299
CYANIDE	72	52	72	UG/L	10	4000
SELENIUM	81	58	72	UG/L	2	1718
BENZENE	41	27	66	UG/L	1	934
BERYLLIUM	81	52	64	UG/L	5	42
TETRACHLOROETHYLENE	41	25	61	UG/L	3	486
PHENOL	42	25	60	UG/L	97	4500
FLUORANTHENE	42	24	57	UG/L	4	37000
PYRENE	42	24	57	UG/L	41	33000
1,2-TRANS-DICHLOROETHYLENE	41	22	54	UG/L	1	12900
CHLOROBENZENE	41	21	51	UG/L	5	1090
1,1-DICHLOROETHANE	41	18	44	UG/L	5	777
PHENANTHRENE	42	18	43	UG/L	27	35000
METHYLENE CHLORIDE	41	17	41	UG/L	1	567
DI-N-BUTYL PHTHALATE	42	17	40	UG/L	40	3066
NAPHTHALENE	42	16	38	UG/L	199	8100
1,2-DICHLOROPROPANE	41	14	34	UG/L	2	53
ANTHRACENE	42	13	31	UG/L	98	35000
CHRYSENE	42	12	29	UG/L	200	15000
1,2-BENZANTHRACENE	42	12	29	UG/L	200	15000
1,4-DICHLOROBENZENE	42	12	29	UG/L	55	3700
CHLOROFORM	41	11	27	UG/L	1	13
1,1,2,2-TETRACHLOROETHANE	41	10	24	UG/L	4	94
BUTYL BENZYL PHTHALATE	42	7	17	UG/L	160	1090
11,12-BENZOFLUORANTHENE	42	7	17	UG/L	85	6200
TRICHLOROFLUOROMETHANE	41	6	15	UG/L	3	353
DICHLOROBROMOMETHANE	41	5	12	UG/L	79	853
1,2,4-TRICHLOROBENZENE	42	5	12	UG/L	2100	15000
THALLIUM	80	8	10	UG/L	8	251
1,1,1-TRICHLOROETHANE	41	4	10	UG/L	7	50
1,2-DICHLOROETHANE	41	4	10	UG/L	17	27
1,2-DICHLOROBENZENE	42	4	10	UG/L	270	590
2,4-DICHLOROPHENOL	42	4	10	UG/L	340	3800
DICHLORODIFLUOROMETHANE	41	3	7	UG/L	26	821
METHYL CHLORIDE	41	3	7	UG/L	1	6

Table H-4. (Part 2 - continued)

PARAMETER	NUMBER OF SAMPLES ANALYZED	NUMBER OF TIMES DETECTED	PERCENT OF SAMPLES WHERE DETECTED	UNITS	MINIMUM VALUE DETECTED	MAXIMUM VALUE
BENZO (A)PYRENE	42	3	7	UG/L	19000	92000
DIETHYL PHTHALATE	42	3	7	UG/L	51	120
FLUORENE	42	3	7	UG/L	230	6300
HEXACHLOROBENZENE	42	3	7	UG/L	47	402
1,3-DICHLOROBENZENE	42	3	7	UG/L	608	4100
ACRYLONITRILE	41	2	5	UG/L	4	119
CHLOROETHANE	41	2	5	UG/L	11	18
ACENAPHTHENE	42	2	5	UG/L	4900	12000
PENTACHLOROPHENOL	42	2	5	UG/L	150	250
1,12-BENZOPERYLENE	42	2	5	UG/L	3000	3500
CARBON TETRACHLORIDE	41	1	2	UG/L	33	33
VINYL CHLORIDE	41	1	2	UG/L	8170	8170
1,1-DICHLOROETHYLENE	41	1	2	UG/L	272	272
1,1,2-TRICHLOROETHANE	41	1	2	UG/L	38	38
ACENAPHTHYLENE	42	1	2	UG/L	52	52

[a] Based on a study in which a total of 50 POTWs were sampled for priority pollutants. Results were reported for two groups of POTWs, comprising 40 plants and 10 plants, respectively. Consult Burns and Roe 1982 for results of sampling at individual plants.

[b] Pollutants not listed were never detected.
Occurrences are based on all influent samples taken.
Pollutants reported as less than the detection limit and unconfirmed pesticides are assumed not detected.

Source: Burns and Roe 1982.

Table H-5. Summary of Minimum Percent Removals Achieved by Secondary Treatment$^{(a,b)}$

	Average Influent > 0					Average Influent > Lower Limit$^{(d)}$		
		Percent of Plants					Percent of Plants	Lower
Parameter	N$^{(c)}$	50	75	80	90	N	50	Limit (ug/l)$^{(e)}$
BOD	40	91	82	81	77	40	91	None
TSS	40	88	84	78	72	40	88	None
Toluene	40	96	88	86	70	25	97	20
Tetrachloroethylene	40	85	67	56	30	21	87	20
Methylene Chloride	40	56	29	27	3	24	55	20
Bis (2-ethylhexyl) Phthalate	40	58	34	32	15	27	63	20
Chloroform	40	62	40	23	11	8	62	20
Trichloroethylene	40	97	87	85	72	25	97	20
1,1,1-Trichloroethane	38	94	85	84	80	23	91	20
Ethylbenzene	39	99+	91	90	86	12	97	20
Phenol	38	99	93	89	46	9	99	20
Di-N-Butyl Phthalate	38	51	13	5	4	4	97	20
1,2-trans-Dichloroethylene	32	99+	96	94	79	4	97	20
Benzene	32	99+	83	74	66	5	99	20
Butyl Benzyl Phthalate	35	99+	97	95	40	3	97	20
Diethyl Phthalate	31	99+	84	74	67	1	96	20
Napthalene	29	99+	99+	98	85	4	99	20
Zinc	40	77	64	55	44	40	77	80
Cyanide	40	59	36	33	5	40	59	4
Copper	40	82	58	56	46	40	82	8
Chromium	40	76	66	64	48	35	76	20
Nickel	36	35	18	17	8	22	32	40
Silver	36	95	82	79	66	2	94	20
Mercury	35	86	65	61	25	9	86	800
Lead	34	97	74	58	35	3	81	200
Cadmium	29	93	46	39	4	12	92	8

Table H-5. Footnotes

[a] Based on a study in which a total of 50 POTWs were sampled for priority pollutants. Results were reported for two groups of POTWs, comprising 40 plants and 10 plants, respectively. Consult Burns and Roe 1982 for results of sampling at individual plants.

[b] Removal based on average influent and effluent concentration.

[c] N = Number of plants meeting average influent criteria.

[d] Lower limit chosen significantly above (approximately 4 times) the parameters's detection limit.

Source: Burns and Roe 1982.

Table H-6. Median Percent Removals of Selected Pollutants Through POTW Treatment Process[a]

PARAMETER	PRIMARY		SECONDARY ACT. SLUDGE[b,c]		SECONDARY TR. FILTER[d]		SECONDARY O_2 ACT. SLUDGE[c]		SECONDARY RBC[e]		SECONDARY AER LAGOON[f]		PARALLEL AS/TF PLANTS[b,g]				TERTIARY M.M. FILT. POL. PONDS[h]	
													A.S. SIDE		T.F. SIDE			
BOD	(12)	19	(22)	90	(5)	77	(3)	91	(1)	92	(1)	80	(4)	92	(4)	82	(8)	93
TOTAL SUSP. SOLIDS	(12)	45	(22)	90	(5)	78	(3)	84	(1)	58	(1)	77	(4)	94	(4)	91	(8)	94
CADMIUM	(6)	15	(6)	85	(1)	11	(2)	83	(0)	-	(1)	44	(2)	91	(2)	84	(3)	78
CHROMIUM	(12)	27	(22)	84	(3)	48	(3)	76	(0)	-	(1)	49	(4)	75	(4)	63	(8)	89
COPPER	(12)	22	(22)	84	(5)	49	(3)	92	(1)	97	(1)	21	(4)	89	(4)	75	(8)	90
CYANIDE	(12)	27	(22)	62	(5)	57	(3)	80	(1)	96	(1)	7	(4)	66	(4)	68	(3)	57
LEAD	(1)	57	(2)	82	(1)	20	(1)	97	(0)	-	(1)	0	(0)	-	(0)	-	(1)	81
MERCURY	(8)	10	(8)	76	(2)	56	(3)	83	(0)	-	(1)	0	(2)	91	(2)	49	(5)	78
NICKEL	(9)	14	(15)	34	(2)	47	(2)	18	(0)	-	(1)	14	(4)	34	(4)	0	(5)	39
SILVER	(4)	20	(5)	83	(2)	55	(2)	80	(0)	-	(1)	0	(2)	79	(2)	83	(1)	75
ZINC	(12)	27	(22)	81	(5)	43	(3)	81	(1)	81	(1)	51	(4)	82	(4)	73	(8)	84
BENZENE	(8)	25	(10)	77	(3)	80	(2)	87	(0)	-	(0)	-	(1)	92	(1)	92	(1)	99
BIS(2-ETHYLHEXYL) PHTHALATE	(12)	0	(8)	62	(5)	24	(3)	64	(1)	86	(1)	23	(4)	87	(4)	72	(8)	65
BUTYL BENZYL PHTHALATE	(4)	62	(2)	94	(1)	70	(3)	84	(0)	-	(1)	93	(1)	80	(1)	93	(3)	86
CHLOROFORM	(11)	14	(20)	62	(5)	75	(3)	50	(0)	-	(0)	-	(3)	75	(4)	69	(7)	41
DI-N-BUTYL PHTHALATE	(3)	36	(6)	68	(5)	50	(1)	98	(0)	-	(1)	50	(1)	97	(3)	50	(0)	-
DIETHYL PHTHLATE	(1)	56	(2)	91	(0)	-	(0)	-	(0)	-	(0)	-	(0)	-	(0)	-	(0)	-
ETHYLBENZENE	(12)	13	(10)	90	(5)	90	(3)	86	(0)	-	(1)	83	(3)	97	(4)	89	(7)	86
METHYLENE CHLORIDE	(12)	0	(14)	48	(5)	76	(3)	34	(0)	-	(1)	96	(4)	52	(4)	32	(8)	78
NAPHTHALENE	(4)	44	(6)	92	(0)	-	(0)	-	(0)	-	(0)	-	(0)	-	(0)	-	(4)	84
PHENOL	(11)	8	(15)	89	(0)	-	(3)	99+	(1)	99+	(1)	50	(3)	89	(3)	94	(6)	95
TETRACHLOROETHYLENE	(12)	4	(20)	82	(5)	82	(3)	75	(1)	50	(1)	91	(4)	76	(4)	62	(8)	94
TOLUENE	(12)	0	(21)	93	(5)	88	(3)	99+	(1)	99+	(1)	89	(4)	97	(4)	93	(8)	98
TRICHLOROETHYLENE	(12)	20	(20)	90	(5)	96	(2)	67	(1)	67	(1)	97	(4)	97	(4)	95	(7)	97
1,1,1-TRICHLOROETHANE	(10)	40	(17)	88	(5)	92	(3)	80	(0)	-	(1)	91	(3)	99+	(3)	91	(7)	96
1,2-TRANS-DICHLOROETHYLENE	(9)	36	(19)	80	(4)	97	(2)	85	(0)	-	(1)	88	(0)	-	(0)	-	(3)	88

[a] Based on a study in which a total of 50 POTWs were sampled for priority pollutants. Results were reported for two groups of POTWs, comprising 40 plants and 10 plants, respectively. Consult Burns and Roe 1982 for results of sampling at individual plants. Number in ( ) is number of plants with calculated removals. Only plants with average influent concentrations greater than three times the most frequent detection limit of each pollutant are included in removal calculations.

[b] POTW 8, which is predominately (96 percent) activated sludge, was included in the activated sludge plants.

[c] ACT = activated.

[d] TR = trickling

[e] RBC = rotating biological contactor

[f] AER = aerated

[g] AS = activated sludge
TF = trickling filter

[h] MM = mixed media
POL = polishing
FILT - filter

Source: Burns and Roe 1982.

Table H-7. Summary of Priority Pollutant Occurrence in Sludge When Not Detected in Influent[a]

PARAMETER[b]	NO. TIMES DETECTED IN ANY SLUDGE STREAM WHEN NOT MEASURED IN POTW INFLUENT	AVERAGE CONCENTRATION IN PRIMARY SLUDGE[c]	AVERAGE CONCENTRATION IN SECONDARY SLUDGE[c]	AVERAGE CONCENTRATION IN COMBINED SLUDGE[c]	AVERAGE CONCENTRATION IN TERTIARY SLUDGE[c]
ARSENIC	181	186 (110)	77 (99)	384 (84)	83 (2)
ANTIMONY	177	141 (109)	54 (78)	422 (80)	6 (2)
SELENIUM	166	73 (90)	25 (79)	107 (81)	6 (2)
PYRENE	145	146 (70)	59 (59)	257 (66)	213 (3)
PHENANTHRENE	137	245 (75)	389 (38)	531 (56)	469 (3)
ANTHRACENE	128	245 (70)	467 (31)	559 (53)	469 (3)
FLUORANTHENE	120	140 (61)	61 (43)	451 (53)	240 (3)
CHRYSENE	95	229 (37)	34 (28)	215 (49)	57 (3)
CADMIUM	93	256 (44)	112 (63)	275 (48)	16 (2)
LEAD	86	7703 (42)	2733 (53)	5987 (47)	1600 (2)
1,2-BENZANTHRACENE	77	248 (32)	23 (23)	223 (39)	57 (3)
BENZENE	73	13 (50)	2 (27)	131 (24)	1 (2)
SILVER	59	350 (34)	297 (28)	402 (21)	110 (1)
1,1-DICHLOROETHANE	58	66 (35)	12 (10)	91 (21)	- (0)
BUTYL BENZYL PHTHALATE	55	1082 (30)	283 (7)	809 (21)	- (0)
1,2-TRANS-DICHLOROETHYLENE	54	400 (44)	29 (13)	984 (13)	- (0)
DI-N-BUTYL PHTHALATE	53	460 (34)	64 (14)	608 (19)	12 (1)
BERYLLIUM	52	42 (25)	29 (9)	37 (33)	- (0)
MERCURY	46	67 (23)	27 (28)	144 (16)	- (0)
1,1,2,2-TETRACHLOROETHANE	45	475 (25)	15 (18)	31 (16)	- (0)
1,4-DICHLOROBENZENE	44	212 (26)	44 (8)	176 (18)	- (0)
1,2-DICHLOROBENZENE	42	246 (29)	42 (9)	339 (13)	- (0)
NAPHTHALENE	40	155 (22)	116 (9)	373 (15)	340 (1)
NICKEL	40	3637 (28)	2144 (15)	6057 (12)	290 (2)
PHENOL	38	516 (21)	248 (23)	899 (15)	- (0)
CHLOROBENZENE	37	17 (20)	5 (7)	150 (16)	- (0)
ETHYLBENZENE	35	115 (25)	4 (7)	418 (15)	- (0)
1,3-DICHLOROBENZENE	34	177 (24)	48 (5)	559 (9)	- (0)

[a] Values in ( ) are number of occurrences. Based on study in which a total of 50 POTWs were sampled for priority pollutants. Results were reported for two groups of POTWs, comprising 40 plants and 10 plants, respectively. Consult Burns and Roe 1982 for results of sampling at individual plants.

[b] All concentrations are in ug/1.

[c] When not detected in corresponding influent.

Source: Burns and Roe 1982.

Table H-8. Summary of Treatment and Slude Handling Processes - Numbers of Plants and Associated Flow - United States Totals[a]

Treatment processes	Number of plants[b]	Total flow (thousands cubic meters per day)[b]
Liquid line		
Pumping, raw wastewater	____[b]	____[b]
Preliminary treatment - raw screen	8,996	110,935
Preliminary treatment - grit removal	____[b]	24,165
Preliminary treatment - comminutors	____[b]	____[b]
Preliminary treatment - others	75	2,593
Scum removal	____[b]	22,674
Flow equalization basins	413	10,928
Preaeration	416	23,715
Primary sedimentation	5,301	102,657
Trickling filter - rock media	2,647	20,841
Trickling filter - plastic media	62	1,816
Trickling filter - redwood slats	40	905
Trickling filter - other media	____[b]	322
Activated sludge - conventional	2,917	75,001
Activated sludge - high rate	40	3,681
Activated sludge - contact stabilization	1,208	12,124
Activated sludge - extended aeration	1,977	5,665
Pure oxygen activated sludge	68	9,650
Bio-disc (rotating, biological filter)	179	1,910
Oxidation ditch using mechanical aerators	553	1,297
Clarification using turf settlers	42	414
Secondary clarification	1,647	13,813
Biological nitrification - separate stage	151	3,279
Biological nitrification - rod and nit.	274	5,168
Biological denitrification	24	498
Post aeration (reaeration)	561	8,550
Microstrainers - primary	28	2,514
Microstrainers - secondary	75	2,315
Sand filters	1,340	9,746
Mix-media filters (sand and coal)	230	8,328
Other filtrations	43	1,061
Activated carbon - granular	21	1,175
Activated carbon - powdered	5	341
Two stage lime treatment or raw wastewater	13	285
Two stage tertiary lime treatment	17	295
Single stage lime treatment of raw wastewater	25	749
Single stage tertiary lime treatment	53	1,605
Recarbonation	26	1,162

Table H-8. (Continued)

Treatment processes	Number of plants	Total flow (thousands cubic meters per day)[b]
Liquid line (continued)		
Neutralization	16	164
Alum addition to primary	73	2,989
Alum addition to secondary	262	6,302
Alum addition to separate stage tertiary	66	1,778
Ferri-chloride addition to primary	42	1,256
Ferri-chloride addition to secondary	165	4,496
Ferri-chloride addition to separate stage tertiary	31	352
Other chemical additions	89	4,214
Ion exchange	2	204
Breakpoint chlorination	10	203
Ammonia stripping	8	302
Dechlorination	182	2,628
Chlorination for disinfection	7,737	81,587
Ozonation for disinfection	22	1,107
Other disinfection	6	3,458
Land treatment of primary effluent	77	82
Land treatment of secondary effluent (30/30)	496	2,975
Land treatment of intermediate effluent	169	343
Stabilization ponds	5,665	12,609
Aerated lagoons	1,166	4,926
Outfall pumping	260	11,874
Outfall diffuser	71	5,081
Effluent to other plants	12	231
Effluent outfall	12,636	109,496
Other treatment	539	6,278
Recalcination	29	2,399
Sludge handling methods		
Aerobic digestion - air	2,960	17,823
Aerobic digestion - oxygen	46	608
Composting	16	2,907
Anaerobic digestion	4,286	78,701
Sludge lagoons	604	14,550
Heat treatment	163	12,999
Chlorine oxidation of sludge (purifax)	36	1,515
Lime stabilization	65	3,011
Wet air oxidation	51	3,172
Air drying	6,688	49,724

Table H-8. (Continued)

Treatment processes	Number of plants	Total flow (thousands cubic meters per day)[b]
Sludge handling methods (continued)		
Dewatering - mechanical - vacuum filter	1,115	51,460
Dewatering - mechanical - centrifuge	209	12,931
Dewatering - mechanical - filter press	102	3,657
Dewatering - others	29	1,748
Gravity thickening	709	38,864
Air flotation thickening	199	15,020
Incineration - multiple hearth	306	26,599
Incineration - fluidized beds	19	1,249
Incineration - rotary kiln	8	236
Incineration - others	13	1,075
Pyrolsis	2	97
Co-incineration with solid waste	5	140
Co-pyrolysis with solid waste	6	14
Co-incineration - others	0	0
Landfill	5,918	66,930
Landspreading of liquid sludge	1,178	11,536
Landspreading of thickened sludge	925	15,514
Trenching	8	1,247
Ocean dumping	49	11,699
Other sludge handling	260	12,574
Digest gas utilization factilities	186	10,664
Miscellaneous		
Control/lab, maintenance buildings	8,204	100,540
Fully automated using digital control	40	6,463
Fully automated using analog controls	77	5,029
Semi automated plant	10,476	108,381
Manually operated and controlled plant	4,398	8,894
Package plant	1,724	1,882
Semi-package plant	1,945	6,608
Custom boilt plant	11,201	119,439
Imhoff tanks	318	327
Septic tanks	____[b]	13
Electrodialysis	0	0
Reverse osmosis	0	0
Pressure filters	3	28
Seepage lagoons	321	78
Rock filters	1	0
Polymer addition to liquid stream	9	954
Polymer addition to sludge stream	8	____[b]

Table H-8. (Footnotes))

[a] Table H-8 summarizes the inventory of unit processes that was compiled during the 1980 Needs Survey, including liquid line, sludge line, and miscellaneous processes and types of controls. In each category the total number of processes is listed along with an associated total flow. The total flow was compiled using the present design flow of the treatment facility using the process. A unit process is defined to mean the complete process. For instance, activated sludge includes the aeration basin, associated blowers and other integral mechanical equipment, and the secondary clarifier, which is not listed separately. Multiple or parallel processes are counted as one process for any single facility. For example, if a facility has four aerobic digesters, the number of aerobic digesters counted in ths summary is one, not four. Therefore, the Number column denotes the number of plants using that rocess.

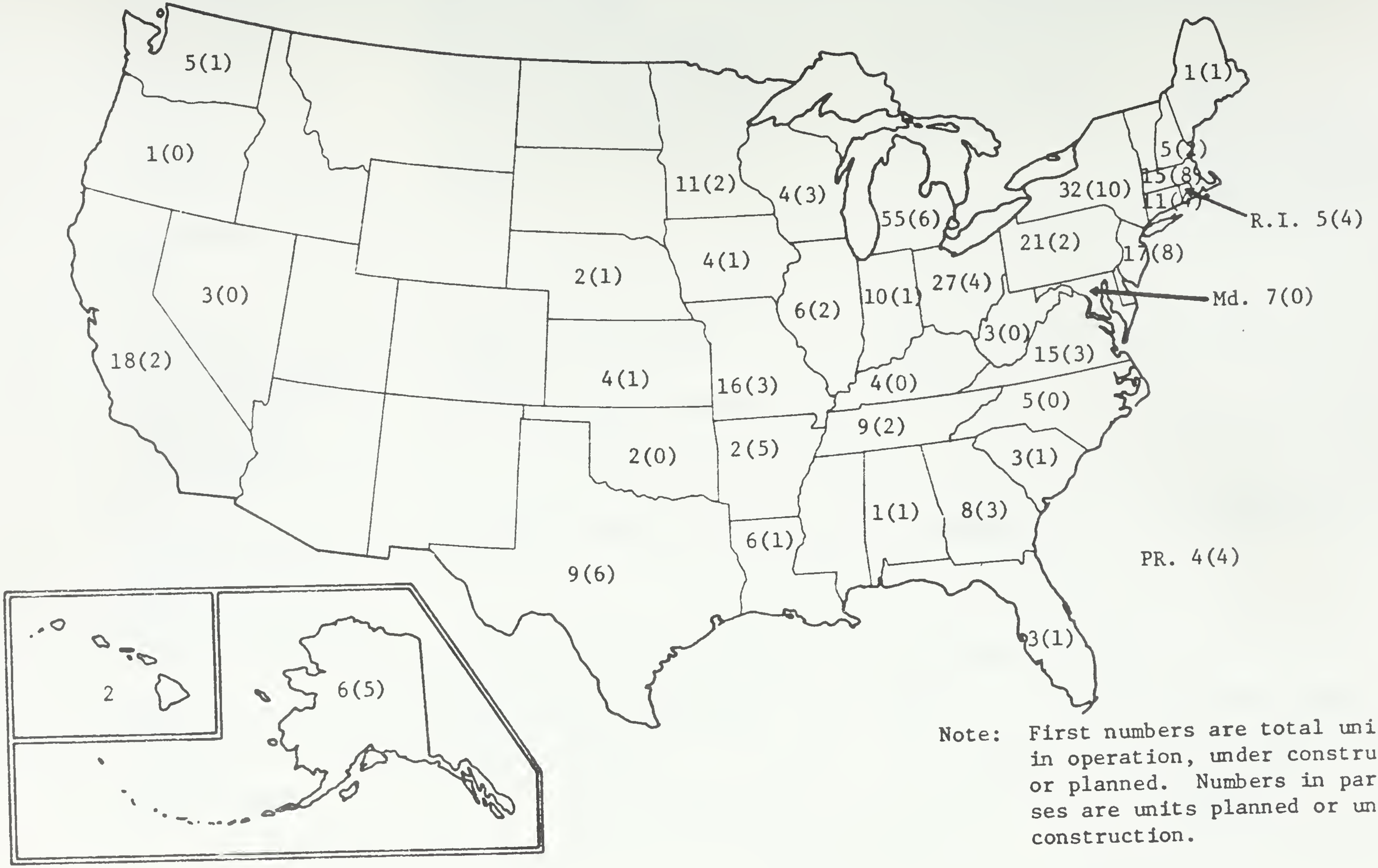
[b] Numbers in original document were illegible.

Source: USEPA 1981e.

APPENDIX I

AUXILIARY INFORMATION ON INCINERATION

Figure I-1. Geographic Distribution of Sewage Sludge Incinerators Proposed, Under Construction, or in Operation, 1978



Note: First numbers are total units in operation, under construction, or planned. Numbers in parentheses are units planned or under construction.

Source: Helfand 1979b.

Table I-1. 1981 Inventory of Resource Recovery Installations from Waste Age Magazine

Location and major participants	Materials and Energy Recovery Facilities		Capacity (tons per day)
	Process	Products	
ARKANSAS			
Batesville City (Mfr. Consumat)	Mass burning in modular incinerator	Steam	50
Blytheville City (Mfr. Consumat)	Mass burning in modular incinerator	Steam	70 (to be processed)
North Little Rock City: U.S. Recycle Corp. (Mfr. Consumat)	Mass burning in modular incinerator	Steam	100
Osceola City (Mfr. Consumat)	Mass burning in modular incinerator	Steam	50
CONNECTICUT			
Bridgeport Conn Resources Recovery Auth. Occidental Petroleum Corp and Combustion Equipment Assoc (designer/operator) Greater Bridgeport Regional Solid Waste Commission	Shredding air classfication magnetic separation Eco-Fuel II production process (aluminum and glass recovery equipment not in use)	Eco-Fuel II (powdered fuel) for use in utility boiler ferrous metals	1800
WINDHAM Town of Windham	Mass burning in modular incinerator	Steam	108

Table I-1. (Continued)

	Materials and Energy Recovery Facilities		
Location and major participants	Process	Products	Capacity (tons per day)
DELAWARE			
Wilmington Delaware Solid Waste Authority, EPA, Raytheon Service Co. (designer)	Shredding air classification magnetic separation froth flotation, other mechanical separation aerobic digestion	Ferrous and nonferrous metals glass, RDF humus humus	1000 tpd municipal solid waste co-processed with 350 tpd of 20% solids digested sewage sludge
FLORIDA			
Dade County (Dade County Solid Waste Resource Recover Plant) County: Parsons & Whitlemore, Inc. (designer/operator)	Hydrasposal$^{\text{TM}}$ (wet pulping) magnetic and other mechanical separation	Steam for utility to produce electricity, aluminum, ferrous metals	3000
Dade County (Agripost Compesting Plant) County: Agripost, Inc. (owner/operator/designer)	Composting	Soil conditioner	400
Jacksonville (Naval Air Station) U.S. Navy	Shredding, magnetic separation trommel screening, mass burning in modular incinerator	Steam	40 design; 20 actual

Table I-1. (Continued)

Location and major participants	Materials and Energy Recovery Facilities		Capacity (tons per day)
	Process	Products	
Lakeland City (operator and joint owner with Orlando Utility Commission); C.T. Main, Inc. (power plant designer) Horner & Shilnn, Inc. (waste processing plant designer)	Shredding, magnetic separation, burning RDF with coal	Steam to produce electricity for use by City of Lakeland and Orlando Utility Commission, ferrous metals	300
Orange County (Walt Disney World) U.S. Dept. of Energy; Idaho Operations Office; Ready Creek Utilities Co.	Slagging pyrolysis incineration (Andco-Torrax)	High temperature water for heating and cooling	100
[a] County County: Florida Power Corp.; UOP Inc.	Mass burning, mechanical separation of metals after burning	Electricity, ferrous metals and nonferrous metals	2000
Pompano Beach Waste Management Inc. U.S. Dept. of Energy, Jacobs Engineering Co. (designer)	Shredding air classification, magnetic and other mechanical separation, anaerobic digestion of air classified light fraction with sewage sludge	Methane gas, carbon dioxide	50-100
HAWAII			
Honolulu City and County of Honolulu, Combustion Engineering, Inc./Amtac	Shredding magnetic separation trommal and other screening, burning RDF in spreader stoker boilers for generation of electricity	Ferrous metals electricity for utility	1800

Table I-1. (Continued)

Location and major participants	Materials and Energy Recovery Facilities		Capacity (tons per day)
	Process	Products	
IDAHO			
Burley Cassia County (Mfr. Consumat)	Mass burning in modular incinerator	Steam	50
ILLINOIS			
Chicago (Northwest incinerator) City Metcalf & Eddy, Inc. (designer)	Mass burning in waterwall incinerators, ferrous recovery from ash (intermittent)	Steam for process use on site and by Brach Candy Co. ferrous metals	1600
Chicago (Southwest Supplementary Fuel Processing Facility) City, Ralph M. Parsons Co. and Consoer, Townsend & Assoc. (designer)	Shredding, air classification, magnetic separation	RDF for use by utility, ferrous metals	1000
IOWA			
Ames City: Gibbs, Hill, Durham & Richardson, Inc. (designer)	Bailing waste paper, shredding, magnetic separation air classification screening, other mechanical separation	RDF for use by utility balad paper, ferrous metals, aluminum, other nonferrous metals	200 (50 tph)
LOUISIANA			
New Orleans City: Waste Management Inc. (owner/operator) National Center for Resource Recovery Inc. (designer/implementer)	Shredding, air classification, magnetic and other mechanical separation	Ferrous metals, aluminum glass	700

Table I-1. (Continued)

Location and major participants	Materials and Energy Recovery Facilities Process	Products	Capacity (tons per day)
MAINE			
Auburn City (Mfr, Consumat)	Mass burning in modular incinerator	Steam	200
MARYLAND			
Baltimore City, EPA	Shredding, pyrolysis in rotary kiln, steam production	Steam for use in heating/air conditioning steam loop by utility	600
Baltimore County County, Maryland Evironmental Service Teledyne National (designer/ operator	Shredding, air classification, magnetic and other mechanical separation pelletizing	RDF ferrous metals glass	1200
MASSACHUSETTS			
Braintree City (owner/operator) Camp. Dresser & McKee Inc. (designer)	Mass burning in waterwall furnace	Steam (half of steam produced used by Art & Leather Co.)	250
East Bridgewater processed City of Brockton and nearby towns. Combustion Equipment Assoc. East Bridgewater Assoc.	Shredding; air classification, magnetic separation other mechanical separation and production of Eco-Fuel® II	Eco-Fuel® II for industrial boiler, ferrous metals	550 being

Table I-1. (Continued)

Location and major participants	Materials and Energy Recovery Facilities		Capacity (tons per day)
	Process	Products	
Haverhill & Lawrence Refuse Fuels, Inc. (owner) BE&C Engineers Inc. (Boeing subsidiary) (design & construction), Cities of Haverhill & Lawrence	Shredding, magnetic separation, trommel screening at recovery facility in Haverhill, burning RDF for cogeneration of steam and electricity in Lawrence	Steam and electricity for industrial use; surplus electricity sold to utility	1300
North Andover UDP, Inc.; MITRE Corp. Mass Bureau of Solid Waste Disposal, Dept. of Environmental Affairs pariticipating communities	Mass burning in waterwall furnace, electricity generation	Electricity for sale to utility, steam	1500
Pittsfield City, Vicon Recovery Assoc.	Mass burning in modular incinerator	Steam	240
Saugus Thirteen communities including Saugus and part of norther Boston RESCO (owner/operator)	Mass burning in waterwall furnaces, magnetic separation	Steam for electical generation and industrial use, ferrous metals	1200
MICHIGAN			
Detroit City, Combustion Engineering Inc./Waste Resources Corp.	Shredding air classification, magnetic separation, burning RDF in dedicated boilers	Steam for use in Detroit Edison's existing steam loop and electricity during off-peak periods, ferrous metals	3000
Genesee Township Township (Mfr. Consumat)	Mass burning in modular incinerator	Steam	100

Table I-1. (Continued)

Location and major participants	Materials and Energy Recovery Facilities		
	Process	Products	Capacity (tons per day)
MINNESOTA			
Collegeville St. John's University Basic Environmental Engineering (designer)	Mass burning in modular incinerator	Steam	70
Duluth Western Lake Superior Sanitary District (owner/operator) Consoer Townsend & Assoc. (designer)	Shredding, magnetic separation, air classification, secondary shredding fluidized bed incineration of RDF and sludge	RDF, ferrous metals steam for heating and cooling of plant and to run process equipment	400 of MSW, 340 of 20% solids sewage sludge
Redwing City (Mfr. Consumat)	Mass burning in modular incinerator	Steam	72
MISSOURI			
Ft. Leonard Wood U.S. Army (Mfr. Environmental Control Technology)	Mass burning in modular incinerator	Steam	75
MONTANA			
Livingston Park County; WIDJAC Corp. (Mfr. Consumat)	Mass burning in modular incinerator	Steam	40

Table I-1. (Continued)

Location and major participants	Materials and Energy Recovery Facilities		
	Process	Products	Capacity (tons per day)
NEW HAMPSHIRE			
Durham (Lamprey Regional Solid Waste Cooperative) Members of cooperative 12 towns, 1 city (Mfr. Consumat)	Mass burning in modular incinerator	Steam	108
Groveton City; Groveton Paper Mill Inc. (Mfr. Environmental Control Products)	Mass burning in modular incinerator	Steam	24
Portsmouth City (Mfr. Consumat)	Mass burning in modular incinerator	Steam	200
NEW YORK			
Albany City and 10 nearby communities, Smith & Mahoney (designer) Aenco Inc. (processing plant operator) N.Y. State (steam plant owner/operator)	Shredding, magnetic separation, burning RDF in semi-suspension stoker-grate boiler, nonferrous recovery from boiler ash	RDF ferrous metals steam for urban heating and cooling, nonferrous metals	750 tons per shift
Glen Cove City (owner/operator) William F. Cosulich and Ernest F.W. Frank (desinger)	Mass burning in stoker-fired furnace with centrifuged sewage sludge	Steam for electricity for use at sewage plant and incinerator	225

Table I-1. (Continued)

	Materials and Energy Recovery Facilities		
Location and major participants	Process	Products	Capacity (tons per day)
Hempstead Town; Hempstead Resources Recovery Corp. (subsidiary of Parsons & Whitlemore, Inc.) (owner/operator)	Hydrasposal™ (wet pulping), magnetic and other separation, burning of RDF in air-swept spout spreader stoker boilers	Electricity from utility-owned turbine generators color-sorted glass, aluminum, ferrous metals	2000 (150 tph)
Monroe County County (owner), Raytheon Service Co. (designer/operator) CH,M Hill (owner's representative)	Shredding, air classification, froth flotation, magnetic and other separation	RDF for use by utility as supplemental boiler fuel, ferrous metals, nonferrous metals, glass	2000
Niagara Falls Hooker Energy Corp. (Hooker Chemicals & Plastics Corp.) (owner/operator)	Shredding, magnetic separation, burning shredded refuse	Steam and electricity for use by company complex, ferrous metals	2200
New York (Belts Avenue Incinerator) City	Mass burning in refractory furnace	Steam for heating and processes in-plant and adjacent City garages	1000 (present throughput 500)
Oceanside Township of Hempstead (owner/operator) Charles R. Velzy (designer)	Mass burning in waterwall furnace	Steam (60,000 lbs/hr) used in-plant for electricity and salt-water conversion process	750
Westchester County (Peekskill) County & 34 municipalities, Wheelabrator-Frye, Inc.	Mass burning in waterwall furnace, ferrous metal recovery from ash	Steam and electricity for sale to utility, ferrous metals	1890

Table I-1. (Continued)

Location and major participants	Materials and Energy Recovery Facilities		
	Process	Products	Capacity (tons per day)
OHIO			
Akron City, Tricll Ltd.	Shredding, magnetic separation, burning RDF in semi-suspension stoker-grate boiler	Steam for urban and industrial heating and cooling, ferrous metals	1000
Columbus City; Aldan E. Stilson Assoc. (designer)	Shredding, magnetic separation, burning of shredded refuse with supplemental coal in semi-suspension stoker-grate boiler to produce steam and generate electricity	Electricity for city customers	2000 (3000 peak)
OREGON			
Lane County County; Allis-Chaimers Corp. (designer), Western Waste Corp. (operator)	Shredding, air classification, magnetic separation	RDF, ferrous metals	500
PENNSYLVANIA			
Harrisburg City; Gannet, Flemming, Corddry and Carpenter, Inc. (designer)	Mass burning of MSW and sewage sludge in waterwall furnace, bulky waste shredding (steam driven), magnetic separation	Steam for utility-owned district heating system and for city owned sludge drying system, ferrous metals	720
RHODE ISLAND			
Warwick R.I. Solid Waste Mgmt. Corp. Widmer & Ernst	Mass burning cogeneration of steam and electricity	Steam for state institutional complex electricity for sale to utility	1200

Table I-1. (Continued)

Location and major participants	Materials and Energy Recovery Facilities		Capacity (tons per day)
	Process	Products	
TENNESSEE			
Crossville City; Environmental Services Corp. (Mfr. Smokatrol, modified by Environmental Control Products, Inc.)	Shredding, mass burning in modular incinerator	Steam	60
Dyersburg City; Colonial Rubber Works (Mfr. Consumat)	Mass burning in modular incinerator	Steam	100
Gallatin Summer County, Cities of Gallatin and Hendersonville Sanders & Thomas, Inc. (designer)	Mass burning in waterwall rotary combustor	Steam for industrial processing and electricity operation	200
Lewisburg City (Mfr. CICO)	Mass burning in modular incinerator	Steam	60
Nashville Nashville Thermal Transfer Corp. I.C. Thomasson & Assoc. Inc. (designer)	Mass burning in waterwall incinerator	Steam for urban heating and cooling	530 (processing 400)

Table I-1. (Continued)

Location and major participants	Materials and Energy Recovery Facilities		
	Process	Products	Capacity (tons per day)
TEXAS			
Gatesville (Texas Dept. of Corrections) Texas Dept. of Corrections (Mfr. Consumat)	Mass burning in modular incinerator	Steam	7
Palestine (Beto Unit. Texas Dept. of Corrections) Texas Dept. of Corrections (Mfr. Consumat)	Mass burning in modular incinerator	Steam	28
VIRGINIA			
Hampton City; NASA Langley Research Center; U.S. Air Force at Langley Field, J.M. Kenith Co. (designer/builder)	Mass burning in waterwall furnace	Steam for use by NASA Langley Research Center	200
Newport News (Ft. Eustis) U.S. Army (Mfr. Consumat)	Mass burning in modular incinerator	Steam	40
Norfolk (Norfold Naval Station) U.S. Navy (owner), Public Works Center, Norfolk Naval Shipyard (operator)	Mass burning in waterwall furnace	Steam for use by facilities at Norfolk Naval Station	360 (two 180 tpd boilers operated alternately)

Table I-1. (Continued)

	Materials and Energy Recovery Facilities		
Location and major participants	Process	Products	Capacity (tons per day)
Portsmouth (Norfolk Naval Shipyard)	Mass burning in waterwall furnace	Steam for use by facilities at shipyard	160 (two 80 tpd boilers, operated alternately)
Portsmouth (Southeastern Tidewater Energy Project) Southeastern Public Service Authority of Va., Henningson, Durham & Richardson (architect/engineer), Day & Zimmerman (construction manager), Norfolk Naval Shipyard	Shredding air classification, magnetic and other separation	RDF for burning in power plant at Naval Shipyard, ferrous and nonferrous metals	2000
Salem City (Mfr. Consumat)	Mass burning in modular incinerator	Steam	100
WASHINGTON			
Tacoma City (owner/operator) Boeing Engineering (designer)	Shredding, air classification, magnetic separation	RDF, ferrous metals	500
WISCONSIN			
Madison City and M.L. Smith Environmental (designer), Madison Gas & Electric Co. (RDF user)	Shredding, magnetic separation, trommel screening, secondary shredding, ferrous metals	RDF burned by utility for electricity generation ferrous metals	400 (max) (250 being processed)

Table I-1. (Continued)

	Materials and Energy Recovery Facilities		
Location and major participants	Process	Products	Capacity (tons per day)
Milwaukee City, Americology Div. of American Can Co. (owner/operator), Bechtel, Inc. (designer)	Shredding, air classification, magnetic separation (nonferrous and glassy aggregate separation not in use)	RDF for use by utility bundled paper and corrugated, ferrous metals	1600
Waukesha City, Donohue & Assoc. (incinerator designer), Sanders & Thomas, Inc. (heat recovery system designer)	Mass burning in refractory furnace	Steam for local industry and sewage treatment plant	175 (design) (120 burning)

Planned Resource Recovery Facilities

- ALABAMA
  - Hunstville (Redstone Arsenal)
  - Opekka
- CALIFORNIA
  - Alameda
  - Berkeley
  - Eureka
  - Gardena
  - Long Beach
  - North Santa Clara County
  - Point Richmond
  - San Siego
  - San Francisco
  - Uklah
- CONNECTICUT
  - Hartford
  - South/Central Connecticut
- FLORIDA
  - Hillsborough County
- GEORGIA
  - Savannah
- IOWA
  - Dubuque
- KENTUCKY
  - Paducah
- MARYLAND
  - Prince Georges County
- MASSACHUSETTS
  - Boston
  - Springfield
- MINNESOTA
  - St. Paul
- MISSOURI
  - Kansas City
  - St Louis
  - Springfield
- NEW JERSEY
  - Camden County
  - Ft. Dix
  - Middlesez County
  - Ocean County
  - Union County
- NEW YORK
  - Babylon, Huntington, Istip (Multi-Town Authority)
  - Bloome County
  - Cattaraugus County
  - New York
  - Onondaga County
  - Oyster Bay
  - Washington County
- OHIO
  - Cincinnati
  - Cuyahoga County
  - Toledo
- OKLAHOMA
  - Oklahoma City
  - Tusla
- OREGON
  - Marion County
  - Portland
- TENNESSES
  - Nashville
  - Memphis
- VERMONT
  - Burlington
- VIRGINIA
  - Petersburg
- WISCONSIN
  - Appleton

Source: Anon. 1981d, Waste Age Survey.

[a]Missing entry due to illegibility of original.

Table I-2. Inventory of Small Municipal Incinerators

Manufacturer	No. of Units	Location	Capacity/Unit kg/day	(tons/day)	Year of Installation	Heat Recovery
U.S. Smelting (Farrier, Smokatrol)	2	Crossville, TN	27,215	(30)	76	Yes
Kelley	1	Nottingham, NH	8,165	(9)	75	No
	1	Candia, NH	12,701	(14)	76	No
	1	Bridgewater, NH	12,701	(14)	76	No
	2	Meredith, NH	12,701	(14)	76	No
	1	Canterbury, NH	8,165	(9)	77	No
	1	Pittsfield, NH	12,701	(14)	77	No
	2	Kittery, ME	21,772	(24)	77	No
	1	Harpswell, ME	12,701	(14)	77	No
	1	Auburn, NH	12,701	(14)	78	No
Consumat	2	Stuttgart, Ark.	27,215	(30)	72	No
	1	Augusta, Ark.	19,958	(22)	72	No
	2	Tahlequah, OK	27,215	(30)	72	No
	1	Donaldsonville, LA	27,215	(30)	72	No
	2	Rayne, LA	27,215	(30)	73	No
	2	Plaquemine, LA	27,215	(30)	73	No
	1	Kensett, AR	14,515	(16)	73	No
	1	Skaneateles, NY	27,215	(30)	73	No
	2	Osceola, AR	27,215	(30)	74	No
	1	Cleveland, OK	19,958	(22)	74	No
	2	Pahokee, FL	19,958	(22)	74	No
	8	Orlando, FL	27,215	(30)	74	No
	1	Refugio, TX	19,958	(22)	74	No
	8	Bellingham, WA	11,793	(13)	74	No
	3	Terrell, TX	16,329	(18)	75	No
	8	Hot Springs, AR	27,215	(30)	75	No
	2	Bentonville, AR	27,215	(30)	75	No
	2	Hope, AR	27,215	(30)	75	No
	2	Siloam Springs, AR	19,958	(22)	75	Yes
	4	Blytheville, AR	16,329	(18)	75	Yes
	2	Wrightsville Beach, NC	27,215	(30)	77	No
	2	Tahlequah, OK	27,215	(30)	77	No
	1	County of Coos, OR	27,215	(30)	77	No
	4	North Little Rock, AR	22,679	(25)	77	No
	4	Port Orange, FL	27,215	(30)	78	No
	1	Atkins, AR	15,422	(17)	78	No
	1	Wilton, NH	27,215	(30)	78	No
	1	Litchfield, NH	19,958	(22)	78	No
	1	Wolfeboro, NH	16,329	(18)	78	No
	1	County of Coos, OR	27,215	(30)	78	No
	4	Salem, VA	22,679	(25)	78	Yes
Total	90	Total Existing Capacity	1,969,488	(2,171)		

Source: Information provided by Ron Myer, EPA Office of Air Quality Planning and Standards.

Table I-3. Inventory of Large Municipal Incinerators in Operation in 1980

State	Unit location
Connecticut	Ansonia, Stanford, New Canaan East Hartford, Bridgport
District of Columbia	SWR Center #1
Florida	Orlando, Dade County
Hawaii	Honolulu (Waipaho)
Illinois	Chicago (N.W.)
Indiana	East Chicago
Kentucky	Louisville
Louisiana	Shreveport
Maryland	Baltimore, Baltimore
Massachusetts	Saugus, Fall River, Braintree, Framingham, E. Bridgewater
Missouri	St. Louis (S. First St) St. Louis (Grand St)
New Jersey	Red Bank
New York	Huntington, Oyster Bay, Tonawanda, Lackawanna, New York City (Betts), New York City (South Brooklyn), New York City (Green Point), Hempstead, Brooklyn (S.W.)
Ohio	Lakewood
Pennsylvania	Harrisburg, Philadelphia (E. Central), Philadelphia (N.W.), Shippensburg, Nashville, Weber County
Tennessee	Nashville
Utah	Weber County
Virginia	Newport News, Norfolk Navy Public Works, Portsmouth
Wisconsin	Sheboygan, Waukesha

Source: Information provided by Ron Myer, EPA Office of Air Quality and Standards.

Table I-4. Manufacturing Segment of the National Industrial Incinerator Population by Use Category

Use	Waste stream	Units in nation
Volume reduction	Solid industrial process	620
	Wood	260
	Trash	620
	TOTAL Volume reduction	1500
Toxicity reduction	Solid industrial process	170
	Liquid industrial process	420
	Sludge	50
	TOTAL Toxicity reduction	640
Resource recovery[a]	Copper wire	400
	Electric motors	1000
	X-ray film	100
	Steel drums	40
	Brake shoes	40
	Other	130
	TOTAL Resource recovery	1700[b]
TOTAL POPULATION		3800[a]

[a] Population figures given are maximums of expected range.

[b] This figure does not equal the sum of its components because it is rounded to 2 significant figures.

Source: USEPA 1980d.

Table I-5. Hazardous Waste Incinerator Vendor Data for the United States

Number	Company	Type Incinerator* Built	Units in HW Service in U.S.	Unit* Capacity	Nature of Wastes	Comments
1	Air Resources	L.I., followed by catalytic converter	1	5 gal/hr.	Liquid	Firm is primarily in fume incin. business. Supplies H.W. incins. only on request
2	Basic Environmental Engineering, Inc.	Pulse Hearth	2	6×10^6 Btu/hr 20×10^6 Btu/hr	Paint Residues residual cutting oils, other	Does not solicit H.W. business
3	Baumco, Inc.	L.I.	0			Primarily a burner vendor
4	Bayco Industries of California	Fixed hearth, Multi-chamber afterburner	512	Mostly 200–300 pph. Up to 600 pph.	Solids, sludges, liquids	
5	Bigelow-Liptak Corp.	L.I. R.K.	19 1	Mostly 7–10 $\times 10^6$ Btu/hr or 30–40 $\times 10^6$ Btu/hr	Mostly chlorinated HC	
6	Brula' C.E. & E., Inc.	L.I.	5	3.5–8.5 $\times 10^6$ Btu/hr	Chlorinated HC	Vendor also mfgs. fume incinerators
7	Burn-Zol Corp.	Fixed Hearth	18	3-100 gph on liquids. 200-1800 pph on solids or solids & liquids	Plating wastes, Paint solvents and sludges, Plastic residues	Vendor also mfgs. fume incinerators
8	C&H Combustion	R.K.	2	10×10^6 Btu (1000-2000 lb)/hr 120×10^6 Btu/hr	Pharmaceutic wastes Commercial industrial wastes	
		L.I.	1	?	Organics, silicones	
9	CEA Combustion, Inc.	L.I. & R.K.	~17 L.I. ~ 3 R.K.	10×10^6 or 30–40 $\times 10^6$ Btu/hr	Liquids, Solids	Also mfgs. fume incinerators. Sees sales trend to R.K.

Table I-5. (Continued)

Number	Company	Type Incinerators Built	Units in HW Service in U.S.	Unit Capacity	Nature of Wastes	Comments
20	Energy, Inc.	F.B.	0			Pilot plant is test burning HW
21	Entech Industrial Systems, Inc.	L.I. and Multiple Hearth	6 L.I. 6 M.H.	50-500 gpd 1000-1500 ppd	liquids solids	Also mfgrs. fume incinerators
22	Environmental Control Products, Inc.	Fixed, stepped hearth	Unk	300-1000 ppb		Also builds incin. for radioactive wastes and for municipal wastes
23	Environmental Elements Corp.	R.K.	0	---	Liquids, solids and fumes	Marketing European technology that is widely used in Europe and Japan
24	Fuller Co.	F.B. & R.K.	Unk	---	---	Has F.B. and R.K. units in operation but nature of wastes is unknown
25	HPD, Inc.	L.I.	0	---	Unit specific for salt-containing organic/aqueous wastes	Unique European technology
26	Hirt Combustion Engineers	L.I.	5-10 (assume 8)	1-10 gpm	Haz. Liquids	All units custom built. Also engineers fume incinerators.
27	Howe-Baker Engineers, Inc.	L.I., R.K.	0	---	---	Company is quoting on several L.I. facilities. Company also manufactures burners.
28	Industronics, Inc.	R.K.	0	---	Liquids and solids	Designs emphasize energy and precious metals recovery. Actively marketing.
29	International Incinerators, Inc.	R.K.	3 +2 in construction	$5\text{-}100 \times 10^6$ Btu/hr	Chlor. H.C. Tars	
30	John Zink Co., The	L.I. (primarily) Oxidative or Starved Air	75 (±10) (since Jan. 1969)	$5\text{-}300 \times 10^6$ Btu/hr Avg. is 30-50 $\times 10^6$ Btu/hr	All types liquids	75% of units sold in last 3 yrs. include heat recovery. Recently, this is 95%. Also mfg. fume incinerators

Table I-5. (continued)

Number	Company	Type Incinerator Built	Units in HW Service in U.S.	Unit Capacity	Nature of Wastes	Comments
10	CE Raymond, Bartlett-Snow Division	R.K., L.I., F.B.	16 R.K. (+3 in construction) 0 L.I. 0 F.B.	$5\text{-}7 \times 10^6$ Btu/hr-6 units 10 " -1 unit 25 " -1 unit 50 " -8 units	Solids, Semi-solids, Liquids	Appears to be the major supplier of R.K.
11	CICO, Inc.	"Semi-suspension" process	0	---	---	Test unit in development
12	Coen Co.	L.I.	2 known; others possibly	75×10^6 and 67×10^6 Btu/hr afterburner for Cin. Municipal L/FI 20,000 gpd unit in construction	Mixed H.W. and Industrial Wastes	
13	Commercial Fabrication and Machine Co., Inc.	"Novel type package incinerator"	0	200 pph		Unit in development. Allegedly usable for H.W.
14	Copeland Associates, Inc.	F.B.	2	$8\text{-}9 \times 10^6$ Btu/hr	Refinery Wastes	
15	Dorr Oliver, Inc.	F.B.	5	35×10^6 Btu/hr 50×10^6 Btu/Hr 2@67 x 10^6 Btu/hr 370 tpd	Pulp Mill Black Liquor Neutral Sulfite Liquor Wet Sludges Contg. Oily Matter	
16	Dravo Engineers and Constructors	R.K., L.I.	0	---	Multiple types of waste	Designs and installs complete H.W. facilities based on Bayer/Steinmuller technology
17	Ecologenics Corp.	Salt Bath	0	---	---	Unit in Development
18	Econo-Therm Energy Systems Corp.	Fixed hearth, w/starved air	≤10	50 to 2500 pph	NA	Also builds cofiring municipal incins. R&D on FB unit
19	Enercon Systems, Inc.	Fixed Hearth	2; possibly others	600 pph 240 tpd	Insecticides Munic. wastes plus liquid H.W.	Also developing a rotary hearth design

Table I-5. (continued)

Number	Company	Type Incinerator Built	Units in HW Service in U.S.	Unit Capacity	Nature of Wastes	Comments
31	Kelley Co., Inc.	Fixed hearth, starved air, for solids and/or liquids	3 in construction	1 @ 9×10^6 Btu/hr 2 @ 3×10^6 Btu/hr	Waste oils, solvents, aqueous solns, contg. organics, solids	
32	Lurgi Corp. (formerly BSP Envirotech)	Fixed Hearth, Multiple Hearth, R.K., F.B.	5 (3 Fixed Hearth 1 Multi-hearth 1 R.K.)- - - - - - - 0 F.B.	1200 pph and some liquids	---	Designs and installs (turnkey) complete facilities
33	McGill, Inc.	L.I.	0	---	---	Now quoting on several units for H.W. service
34	Met-Pro Corporation Systems Div.	R.K., L.I.	2 R.K. 1 L.I.	50 gph/each 120 gph		
35	Midland-Ross Corp.	Rotary Hearth Pyrolyzer	1 (2nd unit near start-up) (assume 2)	3,600 pph 5,800 pph	Organic solids, sludges	Unit touted for use on sludges with large metal content
36	Morse Boulger	Fixed Hearth	3	650-1000 pph	Unk	Relatively new in this business
37	Niro Atomizer Inc.	F.B.	0	---	---	Actively marketing
38	P&T Manufacturing Co.	Fixed Hearth (starved air), R.K.	5 FH 0 RK	25-1000 pph	Paint solvents Chemical slurries	
39	Peabody International Corp.	L.I. single or dual chamber	2 (possibly others)	99×10^6 Btu/hr 41×10^6 Btu/hr	Oil and acid sludge Range of solvents, paints, tars, oils, etc.	Also mfgs fume incinerators, burners, and other related equipment
40	Perstorp, Inc.	Oxidative incin. of H.W. contained in open-end drums	0	---	Liquids and solids	One H.W. facility operating in Sweden
41	Plibrico Co.	F.H.	Unk			Custom-engineered units; not actively marketing
42	Prenco, Inc.	L.I.	~22	3-112 x 10^6 Btu/hr	Varied	

Table I-5. (continued)

Number	Company	Type Incinerator Built	Units in HW Service in U.S.	Unit Capacity	Nature of Wastes	Comments
43	Pyro Magnetics Corp.	Pyrolysis using Induction heating	0	---	---	Constructing a mobile test unit. New company.
44	Rockwell International	Molten Salt Bath	0	---	---	Actively marketing; making quotations in several units
45	Shirco, Inc.	L.I., and Infra-Red, belt-driven chamber w/ or w/o gas-fired afterburner	1 Infra-Red unit in construction 0 LI	50 pph	Phenolic sludges	Infra-Red pilot unit available for testing
46	Sunbeam Equipment Corp., Comtro Div.	Controlled Air 2-stage, F.H.	2 (possibly others)	200 & 800 pph	Solids, plastics wastes	Not highly interested in H.W. market
47	Sur-Lite Corp.	L.I.	3	60, 200 and 500 gph	Oily wastes shale oil residues	
48	TR Systems	R.K.	8	4 @ 1-3 x 10^6 Btu/hr 1 @ 7 " " 1 @ 10 " " 1 @ 20 " " 1 @ 28 " "	Unk	Has proprietary scrubber design
49	Tailor and Co., Inc.	L.I. and F.B.	2 F.B. 0 LI	2 and 10 x 10^6 Btu/hr	Unk	75 x 10^6 Btu/hr. F.B. unit in design
50	Thermal Processes, Inc.	F.B.	0	---	---	
51	ThermAll, Inc.	R.K.	0	---	---	One unit in construction
52	Trane Thermal Co.	L.I.	54	5 to 130 x 10^6 Btu/hr	Chlor. HC; tarry still bottoms, formaldehyde, etc.	Also mfg. fume incinerators
53	Trofe, Inc.	Starved Air, Oscillating, R.K.	0	---		25 x 10^6 Btu/hr. Test unit for liquids, solids and mixtures
54	The United Corporation	L.I.	3	One 10, 6 two 15 x 10^6 Btu/hr		6 x 10^6 Btu/hr. Test unit available

Table I-5. (continued)

Number	Company	Type Incinerator Built	Units in HW Service in U.S.	Unit Capacity	Nature of Wastes	Comments
55	U.S. Smelting Furnace Company	Fixed Hearth	1	4.6 x 10^6 Btu/hr	Solvents	Does not seek H.W. incin. business
56	Vulcan Iron Works, Inc.	R.K.	1	25 tpd	Solids and liquids	
57	Washburn and Granger Co., The, Inc.	Reciprocating grate; controlled air	1	NA	liquids and fumes	

*Abbreviations used: L.I. - Liquid Injection
R.K. - Rotary Kiln
F.B. - Fluidized Bed
F.H. - Fixed Hearth
H.W. - Hazardous Waste
pph - pounds per hour
tpd - tons per day
gpd - gallons per day
gph - gallons per hour
N.A. - Not Available
Unk. - Unknown

Source: List provided by Gene Crumpler, EPA Office of Solid Waste.

Table I-6. Summary of Emission Test Data from Municipal Incinerators, SI Units (English Units)

Pollutant	No. of sources tested	Uncontrolled emissions [mean]		AP-42 emission factor kg/Mg (lb/ton)	Controlled emissions [mean] kg/Mg (lb/ton)
		kg/Mg (lb/ton) feed	ppm		
Particulates	13	0.2 - 19.5 [5.8] (0.3 - 38.1 [11.6])	-	7.5 - 15.0 (15.0 - 30.0)	0.37 - 0.91 [0.48] (0.73 - 1.82 [0.97])
NO_x	3	-	48	1.0 (2.0)	
SO_2	2	10.7 - 16.0 [13.0] (21.32 - 32.0 [26.0])	316-438 [372]	1.3 (2.5)	4 ppm[a]
HC	1	-	30	0.8 - 7.5 (1.5 - 15.0)	
HCl	3	1.0 - 3.5 [2.7] (2.0 - 7.0 [5.35])	98	-	
CO	1	-	6 - 33 [19]	10.0 - 17.5 (20.0 - 35.0)	

[a] Sulfur content of fuel or waste was not given so it is not known if this is a result of the controls of low sulfur feed.

Source: USEPA 1980d.

Table I-7. Summary of Emission Test Data from Liquid Waste Incinerators, SI Units (English Units)

Pollutant	No. of sources tested	Uncontrolled emissions [mean]	AP-42 emission factor kg/Mg (lb/ton)	Controlled emissions [mean]
Particulates	5	4.15 - 7.63 kg/Mg [5.8] (8.3 - 15.26 lb/ton [11.6])	3.5 - 7.5 (7.0 - 15.0)	0.09 - 9.72 kg/Mg [2.91] (0.18 - 19.44 lb/ton [5.81])
SO_2	1	-	1.75 (2.50)	1.07 - 3.06 kg/Mg [1.92] (2.14 - 6.51 lb/ton [3.85])
NO_x	2	180.0 - 933.0 ng/J [417.0] (0.42 - 2.17 lb/10^6 Btu [0.27])	1.0 - 1.5 (2.0 - 3.0)	
HC	2	-	1.5 - 7.5	0.35 - 3.2 kg/Mg [1.26] (0.71 - 6.45 lb/ton [2.53])
HCl	3	0.36 - 0.81 kg/Mg [0.59] (0.72 - 1.61 lb/ton [1.191])	-	0.65 - 3.46 kg/Mg [1.68] (1.31 - 6.92 lb/ton [3.36])
CO	1	-	5.0 - 10.0 (10.0 - 20.0)	13 - 20 ppm @ 50% excess air

Source: USEPA 1980d.

Table I-8. Hazardous Wastes Rated as Good, Potential, or Poor Candidates for Incineration by Appropriate Technologies

EPA hazardous waste number	Hazardous waste	Candidate for incineration			Incinerator type		
		Good	Potential	Poor	Liquid injection	Rotary kiln	Fluidized bed
Generic							
F001	The spent halogenated solvents used in degreasing, tetrachloroethylene, trichloroethylene, methylene chloride, 1,1,1-trichloroethane, carbon tetrachloride, and the chlorinated fluorocarbons: and sludges from the recovery of these solvents in degreasing operations.		✓		✓	✓	✓
F002	The spent halogenated solvents, tetrachloroethylene, methylene chloride, trichloroethylene, 1,1,1-trichloroethane, chlorobenzene, 1,1,2-trichloro-1,2,2-trifluoroethane, o-dichlorobenzene, trichlorofluoromethane and the still bottoms from the recovery of these solvents.		✓		✓	✓	✓
F003	The spent nonhalogenated solvents, xylene, acetone, ethyl acetate, ethyl benzene, ethyl ether, n-butyl alcohol, cyclohexanone, and the still bottoms from the recovery of these solvents.	✓			✓	✓	✓
F004	The spent nonhalogenated solvents, cresols and cresylic acid, nitrobenzene, and the still bottoms from the recovery of these solvents.	✓			✓	✓	✓
F005	The spent nonhalogenated solvents, methanol, toluene, methyl ethyl ketone, carbon disulfide, isobutanol, pyridine and the still bottoms from the recovery of these solvents.	✓			✓	✓	✓
F006	Wastewater treatment sludges from electroplating operations			✓			
F007	Spent plating bath solutions from electroplating operations			✓			
F008	Plating bath sludges from the bottom of plating baths from electroplating operations.			✓			
F009	Spent stripping and cleaning bath solutions from electroplating operations.			✓			
F010	Quenching bath sludge from oil baths from metal heat treating operations.			✓			
F011	Spent solutions from salt bath pot cleaning from metal heat treating operations.			✓			
F012	Quenching wastewater treatment sludges from metal heat treating operations.			✓			
F013	Flotation tailings from selective flotation from mineral metals recovery operations			✓			
F014	Cyanidation wastewater treatment tailing pond sediment from mineral metals recovery operations			✓			
F015	Spent cyanide bath solutions from mineral metals recovery operations			✓			
F016	Dewatered air pollution control scrubber sludges from coke ovens and blast furnaces.			✓			
Wood preservation							
K001	Bottom sediment sludge from the treatment of wastewaters from wood preserving processes that use creosote and/or pentachlorophenol		✓			✓	✓
Inorganic pigments							
K002	Wastewater treatment sludge from the production of chrome yellow and orange pigments			✓			
K003	Wastewater treatment sludge from the production of molybdate orange pigments			✓			
K004	Wastewater treatment sludge from the production of zinc yellow pigments			✓			

Table I-8. (Continued)

EPA hazardous waste number	Hazardous waste	Candidate for incineration			Incinerator type		
		Good	Potential	Poor	Liquid injection	Rotary kiln	Fluidized bed
Inorganic pigments (cont'd)							
K005	Wastewater treatment sludge from the production of chrome green pigments			✓			
K006	Wastewater treatment sludge from the production of chrome oxide green pigments (anhydrous and hydrated)			✓			
K007	Wastewater treatment sludge from the production of iron blue pigments			✓			
K008	Oven residue from the production of chrome oxide green pigments			✓			
Organic chemicals							
K009	Distillation bottoms from the production of acetaldehyde from ethylene		✓				
K010	Distillation side cuts from the production of acetaldehyde from ethylene		✓				
K011	Bottom stream from the wastewater stripper in the production of acrylonitrile		✓				
K012	Still bottoms from the final purification of acrylonitrile in the production of acrylonitrile	✓			✓	✓	✓
K013	Bottom stream from the acetonitrile column in the production of acrylonitrile		✓				
K014	Bottoms from the acetronitrile purification column in the production of acrylonitrile		✓				
K015	Still bottoms from the distillation of benzyl chloride		✓		✓	✓	
K016	Heavy ends or distillation residues from the production of carbon tetrachloride		✓			✓	✓
K017	Heavy ends (still bottoms) from the purification column in the production of epichlorohydrin		✓			✓	✓
K018	Heavy ends from fractionation of ethyl chloride production		✓			✓	✓
K019	Heavy ends from the distillation of ethylene dichloride in ethylene dichloride production		✓			✓	✓
K020	Heavy ends from the distillation of vinyl chloride in vinyl chloride monomer production		✓			✓	✓
K021	Aqueous spent antimony catalyst waste from fluoromethanes production			✓			
K022	Distillation bottom tars from the production of phenol/acetone from cumene	✓				✓	✓
K023	Distillation light ends from the production of phthalic anhydride from naphthalene		✓		✓	✓	✓
K024	Distillation bottoms from the production of phthalic anhydride from naphthalene		✓			✓	✓
K025	Distillation bottoms from the production of nitrobenzene by the nitration of benzene		✓				
K026	Stripping still tails from the production of methyl ethyl pyridines		✓				
K027	Centrifuge residue from toluene diisocyanate production		✓				
K028	Spent catalyst from the hydrochlorinator reactor in the production of 1,1,1-trichloroethane			✓			
K029	Waste from the product stream stripper in the production of 1,1,1-trichloroethane		✓				

Table I-8. (Continued)

EPA hazardous waste number	Hazardous waste	Candidate for incineration			Incinerator type		
		Good	Potential	Poor	Liquid injection	Rotary kiln	Fluidized bed
Organic chemicals (cont'd)							
K030	Column bottoms or heavy ends from the combined production of trichloroethylene and perchloroethylene		√			√	√
Pesticides							
K031	By products salts generated in the production of MSMA and cacodylic acid			√			
K032	Wastewater treatment sludge from the production of chlordane		√				
K033	Wastewater and scrub water from the chlorination of cyclopentadiene in the production of chlordane		√				
K034	Filter solids from the filtration of hexachlorocyclopentadiene in the production of chlordane			√			
K035	Wastewater treatment sludges generated in the production of creosote		√				
K036	Still bottoms from toluene reclamation distillation in the production of disulfoton		√				
K037	Wastewater treatment sludges from the production of disulfoton		√				
K038	Wastewater from the washing and stripping of phorate production		√				
K039	Filter cake from the filtration of diethylphosphorodithoric acid in the production of phorate		√			√	√
K040	Wastewater treatment sludge from the production of phorate			√			
K041	Wastewater treatment sludge from the production of toxaphene		√				
K042	Heavy ends or distillation residues from the distillation of tetrachlorobenzene in the production of 2,4,5-T		√				
K043	2,6-Dichlorophenol waste from the production of 2,4-D		√				
Explosives							
K044	Wastewater treatment sludges from the manufacturing and processing of explosives		√			√	√
K045	Spent carbon from the treatment of wastewater containing explosives	√				√	√
K046	Wastewater treatment sludges from the manufacturing, formulation and loading of lead-based initiating compounds			√			
K047	Pink/red water from TNT operations	√			√	√	√
Petroleum refining							
K048	Dissolved air flotation (DAF) float from the petroleum refining industry	√				√	√
K049	Slop oil emulsion solids from the petroleum refining industry	√				√	√
K050	Heat exchanger bundle cleaning sludge from the petroleum refining industry		√			√	√
K051	API separator sludge from the petroleum refining industry	√				√	√
K052	Tank bottoms (leaded) from the petroleum refining industry		√			√	√
Leather tanning finishing							
K053	Chrome (blue) trimmings generated by the following subcategories of the leather tanning and finishing industry; hair pulp/chrome tan/retan/wet finish, hair save/chrome tan/retan/wet finish; retan/wet finish; no beamhouse; through-the-blue; and shearling			√			

Table I-8. (Continued)

EPA hazardous waste number	Hazardous waste	Candidate for incineration Good	Candidate for incineration Potential	Candidate for incineration Poor	Incinerator type Liquid injection	Incinerator type Rotary kiln	Incinerator type Fluidized bed
Leather tanning finishing (cont'd)							
K054	Chrome (blue) shavings generated by the following subcategories of the leather tanning and finishing industry: hair pulp/chrome tan/retan/wet finish; hair save/chrome tan/retan/wet finish; retan/wet finish; no beamhouse; through-the-blue; and shearling			✓			
K055	Buffing dust generated by the following subcategories of the leather tanning and finishing industry: hair pulp/chrome tan/retan/wet finish; hair save/chrome tan/retan/wet finish; retan/wet finish; no beamhouse; and through-the-blue			✓			
K056	Sewer screenings generated by the following subcategories of the leather tanning and finishing industry: hair pulp/chrome tan/retan/wet finish; hair save/chrome tan/retan/wet finish; retan/wet finish; no beamhouse; through-the-blue; and shearling			✓			
K057	Wastewater treatment sludges generated by the following subcategories of the leather tanning and finishing industry; hair pulp/chrome tan/retan/wet finish, hair save/chrome tan/retan/wet finish; retan/wet finish; no beamhouse; through-the-blue and shearling			✓			
K058	Wastewater treatment sludges generated by the following subcategories of the leather tanning and finishing industry: hair pulp/chrome tan/retan/wet finish; hair save/chrome tan/retan/wet finish; and through-the-blue			✓			
K059	Wastewater treatment sludges generated by the following subcategory of the leather tanning and finishing industry: hair save/nonchrome tan/retan/wet finish			✓			
Iron and steel							
K060	Ammonia still lime sludge from coking operations			✓			
K061	Emission control dust/sludge from the electric furnace production of steel			✓			
K062	Spent pickle liquor from steel finishing operations			✓			
K063	Sludge from lime treatment of spent pickle liquor from steel finishing operations			✓			
Primary copper							
K064	Acid plant blowdown slurry/sludge resulting from the thickening of blowdown slurry from primary copper production			✓			
Primary lead							
K065	Surface impoundment solids contained in and dredged from surface impoundments at primary lead smelting facilities			✓			
Primary zinc							
K066	Sludge from treatment of process wastewater and/or acid plant blowdown from primary zinc production			✓			
K067	Electrolytic anode slimes/sludges from primary zinc production			✓			
K068	Cadmium plant leach residue (iron oxide) from primary zinc production			✓			

Table I-8. (Continued)

EPA hazardous waste number	Hazardous waste	Candidate for incineration			Incinerator type		
		Good	Potential	Poor	Liquid injection	Rotary kiln	Fluidized bed
Secondary lead							
K069	Emission control dust/sludge from secondary lead smelting			√			
Discarded commercial chemical products, off-specification species, containers, and spill residues thereof							
P001	3-(alpha-Acetonylbenzyl)-4-hydroxycoumarin and salts	√			√	√	√
P002	1-Acetyl-2-thiourea		√		√	√	√
P003	Acrolein	√			√	√	√
P004	Aldrin		√			√	√
P005	Allyl alcohol	√			√	√	√
P006	Aluminum phosphide			√			
P007	5-(Aminomethyl)-3-isoxazolol		√			√	√
P008	4-Aminopyridine		√			√	√
P009	Ammonium picrate		√			√	√
P010	Arsenic acid			√			
P011	Arsenic pentoxide			√			
P012	Arsenic trioxide			√			
P013	Barium cyanide			√			
P014	Benzenethiol		√		√	√	√
P015	Beryllium dust			√			
P016	Bis(chloromethyl) ether		√		√	√	√
P017	Bromoacetone		√		√	√	√
P018	Brucine	√				√	√
P019	2-Butanone peroxide	√			√	√	√
P020	2-sec-butyl-4,6-dinitrophenol	√			√	√	√
P021	Calcium cyanide			√			
P022	Carbon disulfide	√			√	√	√
P023	Chloroacetaldehyde		√		√	√	√
P024	p-Chloroaniline	√				√	
P025	1-(p-Chlorobenzoyl)-5-methoxy-2-methylindole-3-acetic acid	√			√	√	
P026	1-(o-Chlorophenyl) thiourea		√			√	
P027	3-Chloropropionitrile		√		√	√	
P028	alpha-Chlorotoluene	√			√	√	
P029	Copper cyanide			√			
P030	Cyanides			√			
P031	Cyanogen	√				√	√
P032	Cyanogen bromide		√			√	√
P033	Cyanogen chloride		√			√	√
P034	2-Cyclohexyl-4,6-dinitrophenol	√				√	√
P035	2,4-Dichlorophenoxyacetic acid (2,4-D)		√			√	
P036	Dichlorophenylarsine			√			
P037	Dieldrin	√				√	
P038	Diethylarsine			√			
P039	0,0-Diethyl-S-[2-(ethylthio)ethyl] ester of phosphorothioic acid		√		√	√	√
P040	0,0-Diethyl-0-(2-pyrazinyl) phosphorothioate	√			√	√	√

Table I-8.(continued)

EPA hazardous waste number	Hazardous waste	Candidate for incineration			Incinerator type		
		Good	Potential	Poor	Liquid injection	Rotary kiln	Fluidized bed
Discarded commercial chemical products, off-specification species, containers, and spill residues thereof (cont'd)							
P041	0,0-Diethyl phosphoric acid, 0-p-nitrophenyl ester		✓		✓	✓	✓
P042	3,4-Dihydroxy-alpha-(methylamino)-methyl benzyl alcohol	✓			✓	✓	✓
P043	Di-isopropylfluorophosphate		✓		✓	✓	✓
P044	Dimethoate		✓			✓	✓
P045	3,3-Dimethyl-1-(methylthio)-2-butanone-O-[(methylamino)carbonyl] oxime		✓			✓	✓
P046	alpha, alpha-dimethylphenethylamine	✓			✓	✓	✓
P047	4,6-Dinitro-o-cresol and salts		✓			✓	✓
P048	2,4-Dinitrophenol		✓			✓	✓
P049	2,4-Dithiobiuret		✓			✓	✓
P050	Endosulfan		✓			✓	
P051	Endrin		✓		✓	✓	
P052	Ethylcyanide	✓			✓	✓	✓
P053	Ethylenediamine	✓			✓	✓	✓
P054	Ethyleneimine	✓			✓	✓	✓
P055	Ferric cyanide			✓			
P056	Fluorine			✓			
P057	2-Fluoroacetamide		✓			✓	✓
P058	Fluoroacetic acid, sodium salt			✓			
P059	Heptachlor		✓			✓	
P060	1,2,3,4,10,10-Hexachloro-1,4,4a,5,8,8a-hexahydro-1,4:5,8-endo, endo-dimethanonaphthalene		✓			✓	✓
P061	Hexachloropropene		✓		✓	✓	✓
P062	Hexaethyl tetraphosphate		✓			✓	✓
P063	Hydrocyanic acid	✓			✓	✓	✓
P064	Isocyanic acid, methyl ester	✓			✓	✓	✓
P065	Mercury fulminate			✓			
P066	Methomyl		✓			✓	✓
P067	2-Methylaziridine	✓			✓	✓	✓
P068	Methyl hydrazine	✓			✓	✓	✓
P069	2-Methyllactonitrile		✓		✓	✓	✓
P070	2-Methyl-2-(methylthio)propionaldehyde-o-(methylcarbonyl) oxime		✓			✓	✓
P071	Methyl parathion		✓			✓	✓
P072	1-Naphthyl-2-thiourea		✓			✓	✓
P073	Nickel carbonyl			✓			
P074	Nickel cyanide			✓			
P075	Nicotine and salts		✓			✓	✓
P076	Nitric oxide			✓			
P077	p-Nitroaniline		✓			✓	✓
P078	Nitrogen dioxide			✓			
P079	Nitrogen peroxide			✓			
P080	Nitrogen tetroxide			✓			
P081	Nitroglycerine	✓			✓	✓	✓
P082	N-Nitrosodimethylamine		✓			✓	✓
P083	N-Nitrosodiphenylamine		✓			✓	✓

(continued)

Table I-8. (Continued)

EPA hazardous waste number	Hazardous waste	Candidate for incineration			Incinerator type		
		Good	Potential	Poor	Liquid injection	Rotary kiln	Fluidized bed
Discarded commercial chemical products, off-specification species, containers, and spill residues thereof (cont'd)							
P084	N-Nitrosomethylvinylamine		✓			✓	✓
P085	Octamethylpyrophosphoramide		✓			✓	✓
P086	Oleyl alcohol condensed with 2 moles ethylene oxide	✓			✓	✓	✓
P087	Osmium tetroxide			✓			
P088	7-Oxabicyclo[2.2.1]heptane-2,3-dicarboxylic acid	✓			✓	✓	✓
P089	Parathion		✓		✓	✓	✓
P090	Pentachlorophenol		✓			✓	
P091	Phenyl dichloroarsine			✓			
P092	Phenylmercury acetate			✓			
P093	N-Phenylthiourea		✓			✓	✓
P094	Phorate		✓		✓	✓	✓
P095	Phosgene		✓			✓	✓
P096	Phosphine		✓			✓	✓
P097	Phosphorothioic acid, O,O-dimethyl ester, O-ester with N,N-dimethyl benzene sulfonamide		✓		✓	✓	✓
P098	Potassium cyanide			✓			
P099	Potassium silver cyanide			✓			
P100	1,2-Propanediol	✓			✓	✓	✓
P101	Propionitrile	✓			✓	✓	✓
P102	2-Propyn-1-ol	✓			✓	✓	✓
P103	Selenourea			✓			
P104	Silver cyanide			✓			
P105	Sodium azide			✓			
P106	Sodium cyanide			✓			
P107	Strontium sulfide			✓			
P108	Strychnine and salts		✓			✓	✓
P109	Tetraethyldithiopyrophosphate		✓			✓	✓
P110	Tetraethyl lead			✓			
P111	Tetraethylpyrophosphate		✓		✓	✓	✓
P112	Tetranitromethane		✓		✓	✓	✓
P113	Thallic oxide			✓			
P114	Thallium selenite			✓			
P115	Thallium (1) sulfate			✓			
P116	Thiosemicarbazide		✓			✓	✓
P117	Thiuram		✓			✓	✓
P118	Trichloromethanethiol		✓			✓	✓
P119	Vanadic acid, ammonium salt			✓			
P120	Vanadium pentoxide			✓			
P121	Zinc cyanide			✓			
P122	Zinc phosphide			✓			
U001	Acetaldehyde	✓			✓		
U002	Acetone	✓			✓	✓	✓
U003	Acetonitrile		✓		✓	✓	✓

Table I-8. (Continued)

EPA hazardous waste number	Hazardous waste	Candidate for incineration			Incinerator type		
		Good	Potential	Poor	Liquid injection	Rotary kiln	Fluidized bed
Discarded commercial chemical products, off-specification species, containers, and spill residues thereof (cont'd)							
U004	Acetophenone	✓			✓	✓	✓
U005	2-Acetylaminoflourene		✓			✓	✓
U006	Acetyl chloride		✓		✓	✓	✓
U007	Acrylamide		✓			✓	✓
U008	Acrylic acid	✓			✓	✓	✓
U009	Acrylonitrile	✓			✓	✓	✓
U010	6-Amino-1,1a,2,8,Ba,8b-hexahydro-8-(hydroxymethyl)B-methoxy-5-methylcarbamate azirino(2',3':3,4) pyrrol0(1,2-a)indole-4, 7-dione (ester)		✓			✓	✓
U011	Amitrole		✓			✓	✓
U012	Aniline	✓			✓	✓	✓
U013	Asbestos			✓			
U014	Auramine		✓			✓	✓
U015	Azaserine			✓			
U016	Benz[c]acridine		✓		✓	✓	
U017	Benzal chloride		✓		✓	✓	
U01B	Benz[a]anthracene	✓			✓	✓	✓
U019	Benzene	✓			✓	✓	✓
U020	Benzenesulfonyl chloride		✓		✓	✓	
U021	Benzidine		✓			✓	✓
U022	Benzo[a]pyrene	✓				✓	✓
U023	Benzotrichloride		✓		✓	✓	
U024	Bis(2-chloroethoxy)methane		✓		✓	✓	✓
U025	Bis(2-chloroethyl) ether		✓		✓	✓	✓
U026	N,N-Bis(2-chloroethyl)-2-naphthylamine	✓				✓	✓
U027	Bis(2-chloroisopropyl) ether		✓		✓	✓	✓
U029	Bromomethane		✓			✓	✓
U030	4-Bromophenyl phenyl ether		✓		✓	✓	✓
U031	n-Butyl alcohol	✓			✓	✓	✓
U032	Calcium chromate			✓			
U033	Carbonyl fluoride		✓			✓	✓
U034	Chloral		✓		✓	✓	✓
U035	Chlorambucil		✓			✓	✓
U036	Chlordane		✓		✓	✓	
U037	Chlorobenzene	✓			✓	✓	
U038	Chlorobenzilate	✓			✓	✓	
U039	p-Chloro-m-cresol	✓				✓	
U040	Chlorodibromomethane		✓			✓	✓
U041	1-Chloro-2,3-epoxypropane		✓		✓	✓	✓
U042	Chloroethyl vinyl ether		✓		✓	✓	✓
U043	Chloroethene		✓			✓	✓
U044	Chloroform		✓		✓	✓	✓
U045	Chloromethane		✓			✓	✓

Table I-8. (Continued)

EPA hazardous waste number	Hazardous waste	Candidate for incineration: Good	Candidate for incineration: Potential	Candidate for incineration: Poor	Incinerator type: Liquid injection	Incinerator type: Rotary kiln	Incinerator type: Fluidized bed
Discarded commercial chemical products, off-specification species, containers, and spill residues thereof (cont'd)							
U046	Chloromethyl methyl ether		✓		✓	✓	✓
U047	2-Chloronaphthalene	✓				✓	✓
U048	2-Chlorophenol	✓			✓	✓	
U049	4-Chloro-o-toluidine hydrochloride		✓		✓	✓	✓
U050	Chrysene	✓				✓	✓
U051	Cresote	✓			✓	✓	✓
U052	Cresols	✓				✓	✓
U053	Crotonaldehyde	✓			✓	✓	✓
U054	Cresylic acid	✓			✓	✓	✓
U055	Cumene	✓			✓	✓	✓
U056	Cyclohexane	✓			✓	✓	✓
U057	Cyclohexanone	✓			✓	✓	✓
U058	Cyclophosphamide		✓			✓	✓
U059	Daunomycin		✓			✓	✓
U060	DDD		✓			✓	
U061	DDT		✓			✓	
U062	Diallate		✓			✓	✓
U063	Dibenz[a,h]anthracene	✓				✓	✓
U064	Dibenzo[a,i]pyrene	✓				✓	✓
U065	Dibromochloromethane		✓		✓	✓	✓
U066	1,2-Dibromo-3-chloropropane		✓		✓	✓	✓
U067	1,2-Dibromoethane		✓			✓	✓
U068	Dibromomethane		✓			✓	✓
U069	Di-n-butyl phthalate	✓			✓	✓	✓
U070	1,2-Dichlorobenzene		✓		✓	✓	
U071	1,3-Dichlorobenzene		✓		✓	✓	
U072	1,4-Dichlorobenzene		✓			✓	
U073	3,3'-Dichlorobenzidine		✓			✓	
U074	1,4-Dichloro-2-butene		✓		✓	✓	✓
U075	Dichlorodifluoromethane		✓			✓	✓
U076	1,1-Dichloroethane		✓		✓	✓	✓
U077	1,2-Dichloroethane		✓		✓	✓	✓
U078	1,1-Dichloroethylene		✓		✓	✓	✓
U079	1,2-trans-dichloroethylene		✓		✓	✓	✓
U080	Dichloromethane		✓		✓	✓	✓
U081	2,4-Dichlorophenol		✓			✓	
U082	2,6-Dichlorophenol		✓			✓	
U083	1,2-Dichloropropane		✓		✓	✓	✓
U084	1,3-Dichloropropane		✓		✓	✓	✓
U085	Diepoxybutane	✓			✓	✓	✓
U086	1,2-Diethylhydrazine	✓				✓	✓
U087	O,O-DiethylS-methyl ester of phosphorodithioic acid		✓		✓	✓	✓
U088	Diethyl phthalate	✓			✓	✓	✓

Table I-8. (Continued)

EPA hazardous waste number	Hazardous waste	Candidate for incineration			Incinerator type		
		Good	Potential	Poor	Liquid injection	Rotary kiln	Fluidized bed
Discarded commercial chemical products, off-specification species, containers, and spill residues thereof (cont'd)							
U089	Diethylstilbestrol	√				√	√
U090	Dihydrosafrole	√				√	√
U091	3,3'-Dimethoxybenzidine	√			√	√	√
U092	Dimethylamine	√				√	√
U093	p-Dimethylaminoazobenzene		√			√	√
U094	7,12-Dimethylbenz[a]anthracene	√				√	√
U095	3,3'-Dimethylbenzidine	√				√	√
U096	alpha-alpha-Dimethylbenzylhydroperoxide	√			√	√	√
U097	Dimethylcarbamoyl chloride		√			√	√
U098	1,1-Dimethylhydrazine		√		√	√	√
U099	1,2-Dimethylhydrazine		√		√	√	√
U100	Dimethylnitrosoamine		√		√	√	√
U101	2,4-Dimethylphenol	√				√	√
U102	Dimethyl phthalate	√			√	√	√
U103	Dimethyl sulfate		√		√	√	√
U104	2,4-Dinitrophenol		√			√	√
U105	2,4-Dinitrotoluene		√			√	√
U106	2,6-Dinitrotoluene		√			√	√
U107	Di-n-octyl phthalate	√			√	√	√
U108	1,4-Dioxane	√			√	√	√
U109	1,2-Diphenylhydrazine		√			√	√
U110	Dipropylamine		√		√	√	√
U111	Di-n-propylnitrosamine		√			√	√
U112	Ethyl acetate	√			√	√	√
U113	Ethyl acrylate	√			√	√	√
U114	Ethylenebisdithiocarbamate		√		√	√	√
U115	Ethylene oxide	√				√	√
U116	Ethylene thiourea		√			√	√
U117	Ethyl ether	√			√	√	√
U118	Ethylmethacrylate	√				√	√
U119	Ethyl methanesulfonate		√		√	√	√
U120	Fluoranthene	√				√	√
U121	Fluorotrichloromethane		√			√	√
U122	Formaldehyde	√				√	√
U123	Formic acid	√			√	√	√
U124	Furan	√			√	√	√
U125	Furfural	√			√	√	√
U126	Glycidylaldehyde	√			√	√	√
U127	Hexachlorobenzene		√			√	
U128	Hexachlorobutadiene		√		√	√	√
U129	Hexachlorocyclohexane		√			√	√
U130	Hexachlorocyclopentadiene		√		√	√	√

Table I-8. (Continued)

EPA hazardous waste number	Hazardous waste	Candidate for incineration			Incinerator type		
		Good	Potential	Poor	Liquid injection	Rotary kiln	Fluidized bed
Discarded commercial chemical products, off-specification species, containers, and spill residues thereof (cont'd)							
U131	Hexachloroethane		✓			✓	✓
U132	Hexachlorophene		✓			✓	✓
U133	Hydrazine		✓		✓	✓	✓
U134	Hydrofluoric acid			✓			
U135	Hydrogen sulfide		✓			✓	✓
U136	Hydroxydimethyl arsine oxide			✓			
U137	Indeno(1,2,3-cd)pyrene	✓				✓	✓
U138	Iodomethane		✓		✓	✓	✓
U139	Iron Dextran			✓			
U140	Isobutyl alcohol	✓			✓	✓	✓
U141	Isosafrole	✓			✓	✓	✓
U142	Kepone	✓				✓	✓
U143	Lasiocarpine		✓			✓	✓
U144	Lead acetate			✓			
U145	Lead phosphate			✓			
U146	Lead subacetate			✓			
U147	Maleic anhydride	✓				✓	✓
U148	Maleic hydrazide		✓			✓	✓
U149	Malononitrile		✓			✓	✓
U150	Melphalan		✓			✓	✓
U151	Mercury			✓			
U152	Methacrylonitrile		✓		✓	✓	✓
U153	Methanethiol		✓			✓	✓
U154	Methanol	✓			✓	✓	✓
U155	Methapyrilene		✓		✓	✓	✓
U156	Methyl chlorocarbonate		✓		✓	✓	✓
U157	3-Methylcholanthrene	✓				✓	✓
U158	4,4'-Methylene-bis-(2-chloroaniline)	✓				✓	✓
U159	Methyl ethyl ketone	✓			✓	✓	✓
U160	Methyl ethyl ketone peroxide	✓			✓	✓	✓
U161	Methyl isobutyl ketone	✓			✓	✓	✓
U162	Methyl methacrylate	✓			✓	✓	✓
U163	N-Methyl-N'-nitro-N-nitrosoguanidine		✓		✓	✓	✓
U164	Methylthiouracil		✓			✓	✓
U165	Naphthalene	✓				✓	✓
U166	1,4-Naphthoquinone	✓				✓	✓
U167	1-Naphthylamine		✓			✓	✓
U168	2-Naphthylamine		✓			✓	✓
U169	Nitrobenzene		✓		✓	✓	✓
U170	4-Nitrophenol		✓			✓	✓
U171	2-Nitropropane		✓			✓	✓
U172	N-Nitrosodi-n-butylamine		✓		✓	✓	✓
U173	N-Nitrosodiethanolamine		✓		✓	✓	✓

Table I-8. (Continued)

EPA hazardous waste number	Hazardous waste	Candidate for incineration			Incinerator type		
		Good	Potential	Poor	Liquid injection	Rotary kiln	Fluidized bed
Discarded commercial chemical products, off-specification species, containers, and spill residues thereof (cont'd)							
U174	N-Nitrosodiethylamine		✓		✓	✓	✓
U175	N-Nitrosodi-n-propylamine		✓		✓	✓	✓
U176	N-Nitroso-n-ethylurea		✓			✓	✓
U177	N-Nitroso-n-methylurea		✓			✓	✓
U178	N-Nitroso-n-methylurethane		✓			✓	✓
U179	N-Nitrosopiperidine		✓		✓	✓	✓
U180	N-Nitrosopyrrolidine		✓		✓	✓	✓
U181	5-Nitro-o-toluidine		✓			✓	✓
U182	Paraldehyde	✓			✓	✓	✓
U183	Pentachlorobenzene		✓			✓	
U184	Pentachloroethane		✓		✓	✓	✓
U185	Pentachloronitrobenzene		✓			✓	✓
U186	1,3-Pentadiene	✓				✓	✓
U187	Phenacetin		✓			✓	✓
U188	Phenol	✓	✓			✓	✓
U189	Phosphorous sulfide		✓			✓	✓
U190	Phthalic anhydride	✓				✓	✓
U191	2-Picoline		✓		✓	✓	✓
U192	Pronamide		✓			✓	✓
U193	1,3-Propane sultone		✓			✓	✓
U194	n-Propylamine		✓			✓	✓
U196	Pyridine		✓		✓	✓	✓
U197	Quinones	✓				✓	✓
U200	Reserpine		✓			✓	✓
U201	Resorcinol	✓				✓	✓
U202	Saccharin		✓			✓	✓
U203	Safrole	✓			✓	✓	✓
U204	Selenious acid			✓			
U205	Selenium sulfide			✓			
U206	Streptozotocin		✓			✓	✓
U207	1,2,4,5-Tetrachlorobenzene		✓		✓	✓	✓
U208	1,1,1.2-Tetrachloroethane		✓		✓	✓	✓
U209	1,1,2,2-Tetrachloroethane		✓		✓	✓	✓
U210	Tetrachloroethane		✓		✓	✓	✓
U211	Tetrachloromethane		✓			✓	✓
U212	2,3,4,6-Tetrachlorophenol		✓			✓	✓
U213	Tetrahydrofuran	✓			✓	✓	✓
U214	Thallium acetate			✓			
U215	Thallium carbonate			✓			
U216	Thallium chloride			✓			
U217	Thallium nitrate			✓			
U218	Thioacetamide		✓			✓	✓
U219	Thiourea		✓			✓	✓

Table I-8. (Continued)

EPA hazardous waste number	Hazardous waste	Candidate for incineration			Incinerator type		
		Good	Potential	Poor	Liquid injection	Rotary kiln	Fluidized bed
Discarded commercial chemical products, off-specification species, containers, and spill residues thereof (cont'd)							
U220	Toluene	✓			✓	✓	✓
U221	Toluenediamine		✓			✓	✓
U222	o-Toluidine hydrochloride		✓		✓	✓	✓
U223	Toluene diisocyanate		✓		✓	✓	✓
U224	Toxaphene		✓			✓	✓
U225	Tribromomethane		✓		✓	✓	✓
U226	1,1,1-Trichloroethane		✓		✓	✓	✓
U227	1,1,2-Trichloroethane		✓		✓	✓	✓
U228	Trichloroethane		✓		✓	✓	✓
U229	Trichlorofluoromethane		✓		✓	✓	✓
U230	2,4,5-Trichlorophenol		✓			✓	
U231	2,4,6-Trichlorophenol		✓			✓	
U232	2,4,5-Trichlorophenoxyacetic acid		✓			✓	
U233	2,4,5-Trichlorophenoxypropionic acid alpha, alpha, alpha-Trichlorotoluene		✓			✓	
U234	Trinitrobenzene		✓			✓	✓
U235	Tris(2,3-dibromopropyl) phosphate		✓			✓	✓
U236	Trypan blue		✓			✓	✓
U237	Uracil mustard		✓			✓	✓
U238	Urethane	✓				✓	✓
U239	Xylene	✓			✓	✓	✓
Other hazardous wastes							
SIC code number							
2865	Vacuum still bottoms from the production of maleic anhydride	✓				✓	✓
2865	Distillation residues from fractionating tower for recovery of benzene and chlorobenzenes		✓			✓	
2865	Vacuum distillation residues from purification of 1-chloro-4-nitrobenzene		✓			✓	✓
2865	Still bottoms or heavy ends from methanol recovery in methyl methacrylate production	✓				✓	✓
2869	Heavy ends and distillation from production of carbaryl	✓				✓	✓
2869	Residues from the production of hexachlorophenol, trichlorophenol and 2,4,5-T		✓			✓	✓
2869	Heavy ends from distillation of ethylene dichloride in vinyl chloride production		✓			✓	✓
2869	Solid waste discharge from ion exchange column in production of acrylonitrile		✓			✓	✓
2869	Bottom stream from quench column in acrylonitrile production of acrylonitrile	✓			✓	✓	✓
2869	Still bottoms from aniline production	✓				✓	✓
2869	Tars from manufacture of bicycloheptadiene and cyclopentadiene	✓				✓	✓
2869	Still bottom from production of furfural	✓				✓	✓
2869	Unrecovered triester from production of disulfoton		✓			✓	✓
2295	Waste polyvinyl chloride (PVC) from the manufacture of coated fabrics		✓			✓	✓
2869	Still bottoms from the production of pentachloronitrobenzene		✓			✓	

Table I-8. (Continued)

EPA hazardous waste number	Hazardous waste	Candidate for incineration Good	Candidate for incineration Potential	Candidate for incineration Poor	Incinerator type Liquid injection	Incinerator type Rotary kiln	Incinerator type Fluidized bed
Other hazardous wastes (cont'd)							
SIC code number							
2869	Process clean out sludges from production of 1,1,1-trichloroethane		✓			✓	✓
2869	Heavy ends and light ends from the production of methyl acrylate	✓				✓	✓
2822	Polyvinyl chloride sludge from the manufacture of polyvinyl chloride		✓			✓	✓
2869	Still bottoms from the purification of fluoromethanes in the production of fluoromethanes		✓			✓	✓
2869	Heavy ends and light ends from the production of ethyl acrylate	✓				✓	✓
2869	Heavy ends from the production of glycerine from allyl chloride	✓				✓	✓
2869	Heavy ends from the distillation of acetic anhydride in the production of acetic anhydride	✓				✓	✓
2869	Light ends from the distillation of acetaldehyde in the production of acetic anhydride	✓			✓	✓	✓
	· Reactor cleanup wastes from the chlorination, dehydrochlorination or oxychlorination of aliphatic hydrocarbons		✓		✓	✓	✓
	· Fractionation bottoms from the separation of chlorinated aliphatic hydrocarbons		✓		✓	✓	✓
	· Distillation bottoms from the separation of chlorinated aliphatic hydrocarbons		✓		✓	✓	✓
	· Reactor cleanup wastes from the chlorination or oxychlorination of cyclic aliphatic hydrocarbons		✓		✓	✓	✓
	· Fractionation bottoms from the separation of chlorinated cyclic aliphatic hydrocarbons		✓		✓	✓	✓
	· Distillation bottoms from the separation of chlorinated cyclic aliphatic hydrocarbons		✓		✓	✓	✓
	· Batch residues from the batch production of chlorinated polymers		✓			✓	✓
	· Solution residues from the production of chlorinated polymers		✓		✓	✓	✓
	· Reactor cleanup wastes from the chlorination of aromatic hydrocarbon		✓		✓	✓	
	· Fractionation bottoms from the separation of chlorinated aromatic hydrocarbons		✓		✓	✓	
	· Distillation bottoms from the separation of chlorinated aromatic hydrocarbons		✓		✓	✓	
3333	Zinc production: oxide furnace residue and acid plant sludge			✓			
3339	Ferromanganese emissions control: baghouse dusts and scrubwater solids			✓			
3339	Ferrochrome silicon furnace emission control dust or sludge			✓			
3339	Ferrochrome emissions control: furnace baghouse dust, and ESP			✓			
3339	Primary antimony-pyrometallurgical blast furnace slag			✓			
3341	Secondary lead, scrubber sludge from SO_2 emission control, soft lead production			✓			

Table I-8. (Continued)

EPA hazardous waste number	Hazardous waste	Candidate for incineration			Incinerator type		
		Good	Potential	Poor	Liquid injection	Rotary kiln	Fluidized bed
Other hazardous wastes (cont'd)							
SIC code number							
3341	Secondary lead-white metal production furnace dust			✓			
3341	Secondary copper-pyrometallurgical, blast furnace slag			✓			
3341	Secondary copper-electrolytic refining wastewater treatment sludge			✓			
3341	Secondary aluminum dross smelting-high salt slag plant residue			✓			
3341	Zinc-cadmium metal reclamation, cadmium plant residue			✓			
3691	Lead acid storage battery production wastewater treatment sludges			✓			
3691	Lead acid storage battery production cleanup wastes from cathode and anode paste production			✓			
3691	Nickel cadmium battery production wastewater treatment sludges			✓			
3691	Cadmium silver oxide battery production wastewater treatment sludges			✓			
3691	Mercury cadmium battery production wastewater treatment sludges			✓			
3692	Magnesium carbon battery production chromic acid wastewater treatment sludges			✓			
2816	Ash from incinerated still bottoms (paint and pigment production)			✓			
2819	Arsenic bearing wastewater treatment sludges from production of boric acid			✓			
2834	Arsenic or organo-arsenic containing wastewater treatment sludges from production of veterinary pharmaceuticals			✓			
2851	Wastewater treatment sludges from paint production			✓			
2851	Air pollution control sludges from paint production			✓			
2869	By-product salts in production of MSMA			✓			
2869	By-product salts in production of cacodylic acid			✓			
2869	Lead slag from lead alkyl production			✓			
3312	Steel Finishing: Alkaline cleaning waste · Waste pickle liquor · Cyanide-bearing wastes from electrolytic coating · Chromate and dichromate wastes from chemical treatment · Descaling acid			✓			
3322	Lead/phenolic sand-casting waste from malleable iron foundries			✓			
3331	Primary copper smelting and refining electric furnace slag, converter dust, acid plant sludge, and reverberatory dust (T)			✓			
3332	Primary lead blast furnace dust			✓			
3339	Primary antimony-electrolytic sludge			✓			
3339	Primary tungsten-digestion residue			✓			
1094	Waste rock and overburden from uranium mining			✓			
1099	Chlorinator residues and clarifier sludge from zirconium extraction			✓			
1475	Overburden and slimes from phosphate surface mining			✓			
2874	Waste gypsum from phosphoric acid production			✓			
2819-2874	Slag and fluid bed prills from elemental phosphorus production			✓			
2812	Sodium calcium sludge from production of chlorine by Down Cell process			✓			
2812	Mercury bearing brine purification muds from mercury cell process in chlorine production			✓			

Table I-8. (Continued)

EPA hazardous waste number	Hazardous waste	Candidate for incineration			Incinerator type		
		Good	Potential	Poor	Liquid injection	Rotary kiln	Fluidized bed
Other hazardous wastes (cont'd)							
SIC code number							
2816	Mercury bearing wastewater treatment sludges from the production of mercuric sulfide pigment			√			
2816	Chromium bearing wastewater treatment sludges from the production of TiO_2 pigment by the chloride process			√			
2816	Arsenic bearing sludges from purification process in the production of antimony oxide			√			
2816	Antimony bearing wastewater treatment sludge from production of antimony oxide			√			
3312	Iron making: Ferromaganese blast furnace dust · Ferromanganese blast burnace sludge · Electric furnace dust and sludge			√			

[a] Use this table for indicative guidance only. For decision making, read the material presented in Monsanto 1981.

Source: Monsanto 1981.

Table I-9. Trial Burn Summaries

Waste	Incinerator	Temperature (°F)	Temperature (°C)	Residence^d time^d, s	Percent excess air	Combustion efficiency	Destruction efficiency^a	Destruction and removal efficiency^b	HCl scrubber efficiency
Aldrin, Shell (20% aldrin granules)	Multiple chamber	1580-2100	860-1150	P 1.4-3.2 S 1.4-3.6	48-155	NR^c	Aldrin >99.99 Total species >99.99		
Aldrite®, Shell 4 aldrin (41.2% emulsifiable concentrate)	Multiple chamber	1120-2080	600-1140	P 1.2-5.9 S 7.6-1.2	70-380	NR	Aldrin >99.99 Total species >99.99		
Atrazine (liquid Aatrex® 4L herbicide)	Multiple chamber	1030-1900	550-1040	P 1.6-7.8 S 1.3-6.9	52-143	NR	>99.99		
Atrazine (solid Aatrex® 80W herbicide)	Multiple chamber	1120-1960	600-1070	P 2.2-6.8 S 2.8-6.4	43-146	NR	Atrazine >99.99 Total species >99.99		
Para-arsanilic acid	Molten salt combustion	1695	924	NR	NR	NR	>99.999		
Captan solid (Ortho Orthcide® 50 wettable)	Multiple chamber	1200-1850	650-1010	P 1.8-6.8 S 1.8-6.5	76-252	NR	Captan >99.99 Total species >99.99		
Chlorodane (5% chlorodane dust 95% inert ingredients)	Liquid injection	1685-2030	918-1110	0.132-0.452	NR	NR	Chorodane >99.99		
Chlorodane (72% emulsifiable concentrate and No.2 fuel oil)	Liquid injection	1780-2005	971-1096	0.140-0.267	45-47.3	NR	Chlorodane >99.999		
Chlorinated aliphatics (28% methylene-chloride, 2% trichloro-ethylene, 70% n-propanol)	Cement kiln	2552-2642	1400-1450	NR	NR		Trichloro-ethylene 99.9998 Methylene chloride 99.995		

Table I-9. (continued)

Waste	Incinerator	Temperature (F)	Temperature (°C)	Residence time^d, s	Percent excess air	Combustion efficiency	Destruction efficiency^a	Destruction and removal efficiency^b	HCl scrubber efficiency
Chloroform	Molten salt combustion	1504	818	NR	NR	NR	>99.999		
DDT (5% oil solution)	Liquid injection	1540->2300	878->1260	0.16-1.30	26-70	NR	>99.99		
DDT (DDT powder, 75% active ingredients)	Municipal multiple hearth sludge incinerator	Trial 1 1107-2337 2 1191-2417 3 1011-2120 4 1450-2822	Trial 1 597-1225 2 644-1325 3 544-1160 4 788-1550	NR	6.5-10.0	NR	Trial 1 99.970 2 99.975 3 99.977 4 99.983		
DDT (10% DDT, dust 90% inert ingrediants)	Multiple chamber	1710-2210	930-1210	P 1.3-2.4 S 1.2-2.5	58-164	NR	DDT >99.99 Total species >99.98		
DDT (20% DDT, 80% aromatic petroleum derivative solvent)	Liquid injection	1730-2000	943-1093	0.139-0.593	42-47	NR	>99.98		
DDT (25% emulsifiable concentrate, 72% aromatic petroleum derivative, and 3% inert ingredients)	Liquid injection	1590-1980	865-1082	0.136-0.727	42-65	NR	>99.9		
DDT (25% emulsifiable concentrate, 18% petroleum oil, 55% xylene, 2% inert ingredients)	Multiple chamber	1700-2180	930-1180	P 0.9-3.0 S 0.7-3.2	64-166	NR	DDT >99.98->99.99 Total species >99.98->99.99		
DDT oil (20% emulsified DDT waste oil, 1.7% PCB)	Thermal oxidizer waste	Trial 1 1600	871	NR	169	NR	DDT NA PCB 99.970		
		2 1600	871	3.36	157	NR	DDT 99.9999 PCB 99.9995		
		3 1600	871	2.94	163	NR	DDT 99.999 PCB 99.9921		
		4 1800	982	3.03	123	NR	DDT 99.9999 PCB 99.9941		
		5 1800	982	3.96	123	NR	DDT 99.9999 PCB 99.9951		

Table I-9. (continued)

Waste	Incinerator	Temperature (F)	Temperature (°C)	Residence time[d], s	Percent excess air	Combustion efficiency	Destruction efficiency[a]	Destruction and removal efficiency[b]	HCl scrubber efficiency
DDT power	Molten salt combustion	1652	900	NR	NR	NR	99.998		
Dieldrin (15% emulsifiable concentrate and 72% chlorodane emulsifiable concentrates. Mixed 1:3 ratio)	Liquid injection	1610–1900	877-1038	0.153-1.171	45.8-51	NR	>99.98		
Diphenylamine-HCL	Molten salt combustion	1692	922	NR	NR	NR	>99.999		
Ethylene manufacturing waste (benzene 20%, toluene 20%, cyclohexadiene 20%, styrene 20%, indene 5%, xylene 2%, napthalene 3%)	Liquid injection	2460–3186	1349–1752	0.14–0.19	NR	NR	Total organics 99.95-99.96 "waste" constituents 99.9999		
GB ($C_4H_{10}O_2PF$) chemical warfare agent	Molten salt combustion	1652-1832	900–1000	NR	NR	NR	Trial 1 99.99999969 2 99.99999976		
Herbicide orange	Two identical refractory lined furnaces on board the M.T. Vulcanus while at sea	Average wall 2323 Average flame 2732	Average wall 1273 Average flame 1500	1.0	45-144	>99.98	2,4-D >99.9 2,4,5-T >99.9 Total hydrocarbon 99.982-99.992 Herbicide orange >99.999 TCDD >99.93->99.99 Chlorinated hydrocarbons, >99.999		
Hexachlorocyclopentadiene	Liquid injection	2458–2512	1348-1378	0.17-0.18		NR	Total organics 94-99.95 Waste constituents >99.999		

Table I-9. (continued)

Waste	Incinerator	Temperature (F)	Temperature (°C)	Residence time^d, s	Percent excess air	Combustion efficiency	Destruction efficiency^a	Destruction and removal efficiency^b	HCl scrubber efficiency
Kepone (in acetic acid)	After burner	1999-2300	1093-1260	2.15-2.44	3.75-4.8		99.98	>99.9999	
Kepone (in Toledo sludge)	Rotary kiln pyrolyzer with afterburner	1900-2000	1038-1093	2.06-2.26	NR	NR		>99.9999	
Lindane (12% emulsifiable concentrate 71% aromatic petroleum, 12% xylene, 5% emulsifier)	Liquid injection	1910-2310	1043-1265	0.132-1.177	31-50	NR	>99.999		
Malathion (dissolved in xylene)	Molten salt combustion	1652	900	NR	NR	NR	99.9999-99.9998		
Malathion (25% wettable 75% inert ingredients)	Multiple chamber	1170-1900	630-1040	P 1.9-5.7 S 1.8-5.6	43-157	NR	Malathion >99.99 Total species >99.99		
Malathion (57% emulsifiable concentrate 33.09% aromatic petroleum, 9.91% inert ingredients)	Multiple chamber	1110-1980	600-1080	P 2.2-6.8 S 2.2-6.5	44-311		Malathion >99.99 Total species >99.99		
Methyl methacrylate (MMA) waste in 38% water	Fluidized bed	1425-1450 1515-1549	Bed average 774-788 Free board average 820-843	12	11.6-13.4	NR	Total organics 99.96-99.98 Constituents >9.999		
0.3% Mirex bait on corncob grit	Multiple chamber	1090-1780	590-940	P 1.7-6.0 S 1.5-6.2	57-225	NR	>98.21-99.98 Total species >97.78-99.96		
Mustard (chemical warfare agent)	Molten salt combustion	1652-1832	900-1000	NR	NR	NR	>99.999985 >99.999982		

Table I-9. (continued)

Waste	Incinerator	Temperature (°F)	Temperature (°C)	Residence time^d, s	Percent excess air	Combustion efficiency	Destruction efficiency^a	Destruction and removal efficiency^b	HCl scrubber efficiency
Nitrochlorobenzene (95% nitrochlorobenzene, 5% dinitrochlorobenzene	Liquid injection	Afterburner 2385-2430	1307-1332	2.3	NR	NR	Total organics 99.84-99.87 Constituents >99.999- >99.99		99.8
Nitroethane	Molten salt combustion	1638	892	NR	NR	NR	>99.993		
Phenol Waste sludge (86% water)	Fluidized bed	Bed average 1364-1394 Free board average 1495-1650	740-754 813-899	12-14	10.7-12.6	NR	Total organics 99.93-99.95 Constituents >99.99		
Picloram Liquid (24.9 Picloram, 75.1% inert ingredients)	Multiple chamber	986-1886	530-1030	P 1.2-7.6 S 1.2-8.0	50-298	>99.99	Picloram >99.99 Total species >99.63- >99.99		
Picloram Tordon 10K pellets	Multiple chamber	1190-1870	640-1020	P 1.3-6.7 S 1.4-7.4	72-227	NR	Picloram >99.99 Total species >99.93 (approx.)		
PCBs (3756 Arochlor 1241/1 mixed with 2/oil)	Rotary kiln with a modified burner	Kiln average 1359-1600 Afterburnar 2304-2410 Hot duct average 2152-2167	737-871 1262-1321 1178-1186	2.63-2.74	NR	99.995- 99.999	99.999968- 99.999977		
PCB Capacitors	Rotary kiln liquid injection burner, afterburner	Kiln 2286-2442 Afterburner 2428-2430	1252-1339 1331-1332	3.0-3.2	NR	NR	Total organics >99.98-99.96 Constituents >99.9999-99.5		99.8
PCB (375 g PCB mixed with 1242 liters of #2 oil)	Cement Kiln	2552-2642	1400-1450	NR	NR	NR	>99.9998		
Polyvinyl chloride waste sludge (72% water, 28% solids)	Rotary kiln with afterburner	1st zone 1600 2nd zone 1800-2000	1st zone 870 2nd zone 980-1090	3	75-140	NR	Total organics 99.80-99.88 Chlorinated organics 99.99		12
Toxaphene (20% toxaphene dust, 80% inert ingredients)	Multiple chamber	1240-1880	670-1030	2.4-7.7 2.8-8.3	44-166		99.99		

Table I-9. (continued)

Waste	Incinerator	Temperature (°F)	Temperature (°C)	Residence time[d], s	Percent excess air	Combustion efficiency	Destruction efficiency[a]	Destruction and removal efficiency[b]	HCl scrubber efficiency
Toxaphene (60% emulsifiable concentrate)	Multiple chamber	Primary 1150-1900	Primary 620-1040	2.2-6.7 2.2-6.5	47-349	NR	99.99		
Trichloroethane	Molten salt combustion	1544	840	NR	NR	NR	>99.999		
2,4-D Low volatile liquid ester (94.8% isooctyl ester O82,4-5D)	Liquid injection	1365-1660	741-904	0.199-0.915	46.8-53.2	NR	>99.89		
2,4,5-T Weedon TM (20% active ingredient)	Municipal multiple hearth sewage sludge incinerator	855-1725	457-940	NR	6-10	NR	99.980- 99.996		
2,4,5-T Herbicide (in isopropanol)	Single hearth furnace with afterburner	1742	950	2-3	NR	NR	99.995		
2,4,5-T Herbicide (in wood chips)	Single hearth furnace with afterburner	932-1562	500-850	0.6-0.7	NR	NR	99.995		
2,4,5-T Herbicide (in wood chips and dry leaves)	Single hearth furnace with afterburner	212	100	1.0	NR	NR	92		
VX ($C_{11}H_{26}O_2PSN$) (Chemical warfare agent)	Molten salt combustion	1652-1832	900-1000	NR	NR	NR	>99.9999945- 99.999989		
Zineb (75% wettable powder Fungicide (25% inert ingedients)	Multiple chamber	1310-1832	710-1000	1.8-5.2 1.7-5.1	62-165	NR	>99.99		

[a]

$$DE = \frac{W_{in} - W_{out}}{W_n} \times 100$$

where: W_{in} = mass feed rate of the principal toxic component

W_{out} = mass emission rate of the principle toxic component leaving incinerator combustion zone (upstream of all pollution control equipment)).

[b]

$$DRE = \frac{W_{in} - W_{out}}{W_{in}} \times 100$$

where: W_{in} = mass feed rate of the principal toxic component

W_{out} = mass emission rate of the principal toxic component in the stack (after all pollution control devices)

[c] NF - No reported.

[d] P - Primary chamber

S - Secondary chamber

Source: Monsanto 1981.

Table I-10. Potential Air Pollutants from Hazardous Waste Incineration

Hazardous waste	Air pollutants[a]	Likely removal sites: Quench tower	Likely removal sites: Scrubber	Likely removal sites: Baghouse or ESP
Organic materials containing:				
1. C, H, O only	Thermal NO_x[b]	-	[c]	-
2. Cl	HCl	X	X	-
3. Br	HBr	X	X	-
4. F	HF	X	X	-
5. S	SO_x	-	X[d]	-
6. P	P_2O_5	-	X[e]	-
7. N	NO_x	-	[c]	-
8. C, N	CH^- compounds	X	X	-
Materials containing some inorganic components:[f]				
1. Nontoxic minerals only, e.g., Al, Ca, Na	Particulate matter	X	X	X
2. Toxic elements including metals, eg., PB, As, Sb	Particulate matter	X	X	X
	Volatile species[g]	-	X[g]	X[g]

[a] Based on complete destruction (i.e., oxidation) of hazardous waste.

[b] NO_x produced from atmospheric nitrogen at high temperatures (about 1,100°C) in the incinerator.

[c] NO_x is not normally controlled. Special scrubbers have been developed for NO_x control in special circumstances.

[d] Alkaline scrubbers are required for efficient SO_x control.

[e] Special high efficiency scrubbers are needed to collect phosphoric acid mist.

[f] A portion of the inorganic components may be removed as bottom ash from the incinerator.

[g] Certain elements from volatile species (e.g., AS_2O_3) that condense out in the exhaust gas as the temperature falls. They can be collected in the gas phase by special scrubbers or as particulate matter at low temperatures by normal particulate control equipment.

Source: Monsanto 1981.

Table I-11. Part 1: Heat of Combustion of Organic Hazardous Constituents from Appendix VIII, 40 CFR Part 261

Hazardous Constituent	H_c/MW kcal/gram
Acetonitrile	7.37
Acetophenone	8.26
3-(alpha-Acetonylbenzyl)-4-hydroxycoumarin and salts (War farin)	7.00*
2-Acetylaminofluorene	7.92*
Acetyl chloride	2.77*
1-Acetyl-2-thiourea	4.55*
Acrolein	6.95
Acrylamide	5.75*
Acrylonitrile	7.93
Aflatoxins	5.73*
Aldrin	3.75*
Allyl alcohol	7.75
4-Aminobiphenyl	9.00
6-Amino-1,1a,2,8,8a,8b-hexahydro-8-(hydroxy-methyl)8a-methoxy 5-methylcarbamate azirino (2',3':3,4)pyrrolo(1,2-a)indole-4,7-dione (ester)(Mitomycin C)	5.41*
5-(Aminomethyl)-3-isoxazolol	4.78
4-Aminopyridine	7.37*
Amitrole	4.01*
Aniline	8.73
Auramine	7.69*
Azaserine	3.21*
Benz(c)acridine	8.92*
Benz(a)anthracene	9.39
Benzene	10.03
Benzenearsonic acid	3.40*
Benzenethiol	8.43
Benzidine	9.18
Benzo(b)fluoranthene	9.25
Benzo(j)fluoranthene	9.25
Benzo(a)pyrene	9.25
Benzoquinone	6.07
Benzotrichloride	3.90*
Benzyl chloride	6.18
Bis(2-chloroethoxy)methane	4.60*
Bis(2-chloroethyl)ether	3.38*
N,N-Bis(2-chloroethyl)-2-naphthylamine	6.64*
Bis(2-chloroisopropyl)ether	4.93*
Bis(chloromethyl)ether	1.97*
Bis(2-ethylhexyl)phthalate	8.42*
Bromoacetone	2.66*
Bromomethane	1.70*
4-Bromophenyl phenyl ether	5.84*
Brucine	7.42
2-Butanone peroxide	6.96*
Butyl benzyl phthalate	8.29*
2-sec-Butyl-4,6-dinitrophenol (DNBP)	5.46*
Chloral(Trichloroacetaldehyde)	0.80*
Chlorambucil	5.93*
Chlordane	2.71*
Chlorinated benzenes, N.O.S.	N/A
Chlorinated ethane, N.O.S.	N/A
Chlorinated fluorocarbons	N/A
Chlorinated naphthalene, N.O.S.	N/A
Chlorinated phenol, N.O.S.	N/A
Chloroacetaldehyde	2.92*
Chloroalkyl ethers	N/A
p-Chloroaniline	6.14*
Chlorobenzene	6.60
Chlorobenzilate	5.50*
p-Chloro-m-cresol	5.08*
1-Chloro-2,3-epoxybutane	5.19*

Table I-11. (Part 1 - continued)

Hazardous Constituent	H_c/MW kcal/gram
2-Chloroethyl vinyl ether	5.19*
Chloroform	.75
Chloromethane	3.25
Chloromethyl methyl ether	3.48*
2-Chloronaphthalene	7.37
2-Chlorophenol	6.89
1-(o-Chlorophenyl)thiourea	5.30*
3-Chloropropionitrile	4.50*
Chrysene	9.37
Citrus Red No. 2	--
Coal tars	N/A
Creosote	N/A
Cresol	8.18
Cresylic Acid	8.09*
Crotonaldehyde	7.73
Cyanogen	6.79
Cyanogen bromide	.81*
Cyanogen chloride	1.29*
Cycasin	3.92*
2-Cyclohexyl-4,6-dinitrophenol	5.74*
Cyclophosphamide	3.97*
Daunomycin	5.70*
DDD	5.14*
DDE	5.05*
DDT	4.51*
Diallate	5.62*
2,4-D	3.62*
Dibenz(a,h)acridine	9.53*
Dibenz(a,j)acridine	9.53*
Dibenz(a,h)anthracene(Dibenzo(a,h)anthracene)	9.40*
7H-Dibenzo(c,g)carbazole	8.90*
Dibenzo(a,e)pyrene	9.33*
Dibenzo(a,h)pyrene	9.33*
Dibenzo(a,i)pyrene	9.33*
1,2-Dibromo-3-chloropropane	1.48*
1,2-Dibromoethane	1.43*
Dibromomethane	0.50*
Di-n-butyl phthalate	7.34*
Dichlorobenzene, N.O.S.	4.57
3,3'-Dichlorobenzidine	5.72*
1,4-Dichloro -2-butene	4.27*
Dichlorodifluoromethane	0.22*
1,1-Dichloroethane	3.00
1,2-Dichloroethane	3.00
trans-1,2-Dichloroethene	3.00
Dichloroethylene, N.O.S.	2.70
1,1-Dichloroethylene	2.70
Dichloromethane	1.70
Dichloromethylbenzene	5.09*
2,4-Dichlorophenol	3.81*
2,6-Dichlorophenol	3.81*
Dichloropropane	3.99
Dichlorophenylarsine	2.31*
1,2-Dichloropropane	3.99
Dichloropropanol, N.O.S.	2.84
Dichloropropene, N.O.S.	3.44*
1,3-Dichloropropene	3.44*
Dieldrin	5.56*
Diepoxybutane	5.74
Diethylarsine	5.25*
1,2-Diethylhydrazine	8.68*
Diethyl phthalate	6.39
Dihydrosafrole	7.66*

Table I-11. (Part 1 - continued)

Hazardous Constituent	H_c/MW kcal/gram
3,4-Dihydroxy-alpha-(methylamino)-methyl benzyl alcohol	6.05*
Dimethoate	4.02
3,3'-Dimethoxybenzidine	7.36*
p-Dimethylaminoazobenzene	6.97*
7,12-Dimethylbenz(a)anthracene	9.61
3,3'-Dimethylbenzidine	8.81*
Dimethylcarbamoyl chloride	5.08*
1,1-Dimethylhydrazine	7.87
1,2-Dimethylhydrazine	7.87
3,3-Dimethyl-1-(methylthio)-2-butanone-O-(methylamino)carbonyl oxime	5.82*
Dimethylnitrosoamine	5.14*
alpha,alpha-Dimethylphenethylamine	9.54*
2,4-Dimethylphenol	8.51
Dimethyl phthalate	5.74
Dimethyl sulfate	2.86
Dinitrobenzene, N.O.S.	4.15
4,6-Dinitro-o-cresol and salts	4.06*
2,4-Dinitrophenol	3.52
2,4-Dinitrotoluene	4.68
2,6-Dinitrotoluene di-n-octyl phthalate	6.67*
1,4-Dioxane	6.41
Diphenylamine	9.09
1,2-Diphenylhydrazine	8.73*
Di-n-propylnitrosamine	7.83*
Disulfoton	5.73*
2,4-Dithiobiuret	2.12*
Endosulfan	2.33*
Endrin	3.46*
Ethyl carbamate	4.73*
Ethylenebisdithiocarbamate	5.70*
Ethyl cyanide	4.57
Ethyleneimine	7.86*
Ethylene oxide	6.86
Ethylenethiourea	5.98*
Ethyl methacrylate	7.27*
Fluoranthene	9.35
2-Fluoroacetamide	3.24
Formaldehyde	4.47
Formic acid	1.32
Glycidylaldehyde	5.74
Halomethane, N.O.S.	N/A
Heptachlor	2.96*
Heptachlor epoxide	2.71*
Hexachlorobenzene	1.79
Hexachlorobutadiene	2.12*
Hexachlorocyclohexane (all isomers)	1.12*
Hexachlorocyclopentadiene	2.10*
Hexachloroethane	.46
1,2,3,4,10,10-Hexachloro-1,4,4a,5,8,8a-hexahydro-1,4:5,8-endo, endo-dimethanonaphthalene	3.38*
Hexachlorophene	3.82*
Hexachloropropene	0.70*
Hydrazine	4.44*
Indeno(1,2,3-c,d)pyrene	8.52*
Iodomethane	1.34
Isocyanic acid, methyl ester	4.69*
Isobutyl alcohol	8.62
Isosafrole	7.62
Kepone	2.15*
Lasiocarpine	--
Maleic anhydride	3.40

Table I-11. (Part 1 - continued)

Hazardous Constituent	H_c/MW kcal/gram
Maleic hydrozide	4.10*
Malononitrile	5.98
Melphalan	5.21*
Methacrylonitrile	8.55*
Methanethiol	5.91*
Methapyrilene	7.93*
Methomyl	5.20*
Methoxychlor	5.59*
2-Methylaziridine	9.09*
3-Methylcholanthrene	9.57*
4,4'-Methylene-bis-(2-chloroaniline)	4.84*
Methyl ethyl ketone (MEK)	8.07
Methyl hydrazine	6.78*
2-Methyllactonitrile	6.43
Methyl methacrylate	6.52*
Methyl methanesulfonate	3.74
2-Methyl-2-(methylthio)propionaldehyde-o-(methylcarbonyl) oxime	5.34*
N-Methyl-N'-nitro-N-nitrosoguanidine	4.06*
Methylparathion	4.00*
Methylthiouracil	4.79*
Mustard gas	4.06*
Naphthalene	9.62
1,4-Naphthoquinone	6.97
1-Naphthylamine	8.54
2-Naphthylamine	8.54
1-Naphthyl-2-thiourea	7.50*
Nicotine and salts	8.92*
p-Nitroaniline	5.50
Nitrobenzene	5.50
Nitrogen mustard and hydrochloride salt	4.28*
Nitrogen mustard N-Oxide and hydrochloride salt	3.56
Nitroglycerine	3.79
4-Nitrophenol	4.95
4-Nitroquinoline-1-oxide	5.59
5-Nitro-o-toluidine	5.98
Nitrosamine, N.O.S.	N/A
N-Nitrosodi-N-butylamine	8.46*
N-Nitrosodiethanolamine	7.02*
N-Nitrosodiethylamine	6.86*
N-Nitrosodimethylamine	5.14*
N-Nitroso-N-ethylurea	3.92*
N-Nitrosomethylethylamine	6.13*
N-Nitroso-N-methylurea	2.89*
N-Nitroso-N-methylurethane	4.18*
N-Nitrosomethylvinylamine	7.91*
N-Nitrosomopholine	5.22*
N-Nitrosonornicotine	7.07*
N-Nitrosopiperidine	7.04*
N-Nitrosopyrrolidine	6.43*
N-Nitrososarcosine	3.19*
Octamethylpyrophosphoramide	
7-Oxabicyclo(2.2.1)heptane-2,3-dicarboxylic acid	4.70*
Paraldehyde	6.30*
Parathion	3.61*
Pentachlorobenzene	2.05*
Pentachloroethane	0.53*
Pentachloronitrobenzene(PCNB)	1.62*
Pentachlorophenol	2.09
Phenacetin	7.17
Phenol	7.78
Phenylenediamine	7.81
Phenyl dichloroarsine	3.12*

Table I-11. (Part 1 - continued)

Hazardous Constituent	H_c/MW kcal/gram
Phenylmercury acetate	2.71*
N-Phenylthiourea	6.93*
Phthalic acid esters, N.O.S.	N/A
Phthalic anhydride	5.29
2-Picoline	8.72
Polychlorinated biphenyl, N.O.S.	Regulated under 40 CFR 60
Pronamide	5.72*
1,3-Propane sultone	3.67*
n-Propylamine	9.58
Propylthiouracil	6.28*
2-Propyn-1-ol	7.43*
Pyridine	7.83
Reserpine	6.70*
Resorcinol	6.19
Saccharin	4.49*
Safrole	7.68
Strychnine and salts	8.03
2,4,5-TP	5.58*
2,4,5-T	2.87*
1,2,4,5-Tetrachlorobenzene	2.61*
TCDD	3.43*
Tetrachloroethane, N.O.S.	1.39
1,1,1,2-Tetrachloroethane	1.39
1,1,2,2-Tetrachloroethane	1.39
Tetrachloroethene (Tetrachloroethylene)	1.19
Tetrachloromethane	0.24
2,3,4,6-Tetrachlorophenol	2.23*
Tetraethyl lead	4.04*
Tetranitromethane	0.41*
Thioacetamide	5.95*
Thiosemicarbazide	4.55
Thiourea	4.51
Thiuram	5.85*
Toluene	10.14
Toluene diamine	8,24*
o-Toluidine hydrochloride	6.63*
Tolylene diisocyanate	5.92*
Toxaphene	2.50*
Tribromomethane	0.13
1,2,4-Trichlorobenzene	3.40*
1,1,1-Trichloroethane	1.99
1,1,2-Trichloroethane	1.99
Trichloroethene (Trichloroethylene)	1.74
Trichloromethanethiol	0184*
Trichloromonofluoro methane	0.11*
2,4,5-Trichlorophenol	2.88*
2,4,6-Trichlorophenol	2.88*
Trichloropropane, N.O.S.	2.81
1,2,3-Trichloropropane	2.81
Trypan blue	3.84*
Uracil mustard	4.00*
Vinyl Chloride	4.45*

*Computed by method of Handrick, Ind. Eng. Che., 48:1366 (1956).
N/A: Not applicable, see individual constituents.
Sources: Lange's Handbook of Chemistry, 11th Edition, McGraw-Hill, 1973
Cox and Pilcher, Thermochemistry of Organic and Organo-metallic Compounds, Academic Press, London, 1970.

Table I-11. Part 2: Ranking of Incinerability of Organic Hazardous Constituents from Appendix VIII, 40 CFR Part 261, on the Basis of Heat of Combustion

Hazardous Constituent	Heat of Combustion kcal/gram
Trichloromonofluoromethane	0.11
Tribromomethane	0.13
Dichlorodifluoromethane	0.22
Tetrachloromethane	0.24
Tetranitromethane	0.41
Hexachloroethane	0.46
Dibromomethane	0.50
Pentachloroethane	0.53
Hexachloropropene	0.70
Chloroform	0.75
Chloral(trichloroacetaldehyde)	0.80
Cyanogen bromide	0.81
Trichloromethanetiol	0.84
Hexachlorocyclohexane	1.12
Tetrachloroethene (Tetrachloroethylene)	1.19
Cyanogen chloride	1.29
Formic acid	1.32
Iodomethane	1.34
Tetrachloroethane, N.O.S.	1.39
1,1,1,2-Tetrachloroethane	1.39
1,1,2,2-Tetrachloroethane	1.39
1,2-Dibromomethane	1.43
1,2-Dibromo-3-chloropropane	1.48
Pentachloronitrobenzene	1.62
Bromomethane	1.70
Dichloromethane	1.70
Trichloroethene (Trichloroethylene)	1.74
Hexachlorobenzene	1.79
Bis (chloromethyl) ether	1.97
1,1,1-Trichloroethane	1.99
1,1,2-Trichloroethane	1.99
Pentachlorobenzene	2.05
Pentachlorophenol	2.09
Hexachlorocyclopentadiene	2.10
Hexachlorobutadiene	2.12
Kepone	2.15
2,3,4,6-Tetrachlorophenol	2.23
Dichlorophenylarsine	2.31
Endosulfan	2.33
Toxaphene	2.50
1,2,4,5-Tetrachlorobenzene	2.61
Bromoacetone	2.66
Dichloroethylene, N.O.S.	2.70
1,1-Dichloroethylene	2.70
Chlordane	2.71
Heptachlor epoxide	2.71
Phenylmercury acetate	2.71
Acetyl chloride	2.77
Trichloropropane, N.O.S.	2.81
1,2,3-Trichloropropane	2.81
Dichloropropanol, N.O.S.	2.84
Dimethyl sulfate	2.86
2,4,5-T	2.87
2,4,5-Trichlorophenol	2.88
2,4,6-Trichlorophenol	2.88
N-Nitroso-N-methylurea	2.89

Table I-11. (Part 2 - continued)

Hazardous Constituent	Heat of Combustion kcal/gram	Hazardous Constituent	Heat of Combustion kcal/gram
1,1-Dichloroethane	3.00	Trypan blue	3.84
1,2-Dichloroethane	3.00	Benzotrichloride	3.90
trans-1,2-Dichloroethane	3.00	Cycasin	3.92
Phenyl dichloroarsine	3.12	N-Nitroso-N-ethylurea	3.92
N-Nitrososarcosine	3.19	Cyclophosphamide	3.97
Azaserine	3.21	Dichloropropane, N.O.S.	3.99
2-Fluoroacetamide	3.24	1,2-Dichloropropane	3.99
Chloromethane	3.25	Methylparathion	4.00
Bis (2-chloroethyl) ehter	3.38	Uracil mustard	4.00
1,2,3,4,10,10-Hexachloro-1,4,4a,5,7,8a-hexahydro-1,4:5,8-endo, endo-dimethanonaphthalene	3.38	Amitrole	4.01
		Dimethoate	4.02
Benzenearsonic acid	3.40	Tetraethyl lead	4.04
Maleic anhydride	3.40	4,6-Dinitro-o-cresol and salts	4.06
1,2,4-Trichlorobenzene	3.40	N-Methyl-N -nitro-N-nitrosoguanidine	4.06
TCDD	3.43	Mustard gas	4.06
Dichloropropene, N.O.S.	3.44	Maleic hydrazide	4.10
1,3-Dichloropropene	3.44	Dinitrobenzene, N.O.S.	4.15
Endrin	3.46	N-Nitroso-N-methylurethane	4.18
Chloromethyl methyl ether	3.48	1,4-Dichloro-2-butene	4.27
2,4-Dinitrophenol	3.52	Nitrogen mustard and hydrochloride salt	4.28
Nitrogen mustard N-oxide and hydrochloride salt	3.56	Hydrazine	4.44
		Vinyl chloride	4.45
Parathion	3.61	Formaldehyde	4.47
2,4-D	3.62	Saccharin	4.49
1,3-Propane sultone	3.67	3-Chloropropionitrile	4.50
Methyl methanesulfonate	3.74	DDT	4.51
Aldrin	3.75	Thiourea	4.51
Nitroglycerine	3.79	1-Acetyl-2-thiourea	4.55
2,4-Dichlorophenol	3.81	Thiosemicarbazide	4.55
2,6-Dichlorophenol	3.81	Dichlorobenzene, N.O.S.	4.57
Hexachlorophene	3.82	Ethyl cyanide	4.57

Table I-11. (Part 2 - continued)

Hazardous Constituent	Heat of Combustion kcal/gram
Bis (2-chloroethoxy) methane	4.60
2,4-Dinitrotoluene	4.68
Isocyanic acid, methyl ester	4.69
7-Oxabicyclo (2.2.1) heptane-2,3-dicarboxylic acid	4.70
Ethyl carbamate	4.73
5-(Aminomethyl)-3-isoxazolol	4.78
Methylthiouracil	4.79
4,4'-Methylene-bis-(2-chloroaniline)	4.84
Bis (2-chloroisopropyl) ether	4.93
4-Nitrophenol	4.95
DDE	5.05
Dimethylcarbamoyl chloride	5.08
p-Chloro-m-cresol	5.08
Dichloromethylbenzene	5.09
DDD	5.14
Dimethylnitrosoamine	5.14
N-Nitrosodimethylamine	5.14
1-Chloro-2,3-epoxybutane	5.19
2-Chloroethyl vinyl ether	5.19
Methomyl	5.20
Melphalan	5.21
N-Nitrosomorpholine	5.22
Diethylarsine	5.25
Phthalic anhydride	5.29
1-(o-chlorophenyl) thiourea	5.30
2-Methyl-2-(methylthio) propionaldehyde-o-(methylcarbonyl) oxime	5.34
2-sec-Butyl-4,6 dinitrophenol (DNBP)	5.46
p-Nitroaniline	5.50
Chlorobenzilate	5.50
Dieldrin	5.56
2,4,5-TP	5.58
Methoxychlor	5.59
4-Nitroquinoline-1-oxide	5.59
Diallate	5.62
Daunomycin	5.70
Ethylenebisdithiocarbamate	5.70
3,3'-Dichlorobenzidine	5.72
Pronamide	5.72
Aflatoxins	5.73
Disulfoton	5.73
4,6-Dinitrophenol	5.74
Diepoxybutane	5.74
Dimethyl phthalate	5.74
Glycidylaldehyde	5.74
Acrylamide	5.75
3,3-Dimethyl-1-(methylthio)-2-butanone-O-(methylamino)carbonyl oxime	5.82
4-Bromophenyl phenyl ether	5.84
Thiuram	5.85
Methanethiol	5.91
Tolylene diisocyanate	5.92
Chlorambucil	5.93
Thioacetamide	5.95
Ethylenethiourea	5.98
Malononitrile	5.98
5-Nitro-o-toluidine	5.98
Nitrobenzene	6.01
3,4-Dihydroxy-alpha-(methylamino)methyl benzyl alcohol	6.05
Benzoquinone	6.07

Table I-11. (Part 2 - continued)

Hazardous Constituent	Heat of Combustion kcal/gram	Hazardous Constituent	Heat of Combustion kcal/gram
N-Nitrosomethylethylamine	6.13	Phenacetin	7.17
p-Chloroaniline	6.14	Ethyl methacrylate	7.27
Benzyl chloride	6.18	Di-n-butyl phthalate	7.34
Resorcinol	6.19	3,3'-Dimethoxybenzidine	7.36
Propylthiouracil	6.28	Acetonitrile	7.37
Paraldehyde	6.30	4-Aminopyridine	7.37
Diethyl phthalate	6.39	2-Chloronaphthalene	7.37
Dioxane	6.41	2 Propyn-1-ol	7.43
2-Methyllactonitrile	6.43	1-Naphthyl-2-thiourea	7.50
N-Nitrosopyrrolidone	6.43	Isosafrole	7.62
Methyl methacrylate	6.52	Dihydrosafrole	7.66
Chlorobenzene	6.60	Safrole	7.68
o-Toluidine hydrochloride	6.63	Auramine	7.69
N,N-Bis (2-chloroethyl)-2-naphthylamine	6.64	Crotonaldehyde	7.73
2,6-Dinitrotoluene di-n-octyl phthalate	6.67	Allyl alcohol	7.75
Reserpine	6.70	Phenol	7.78
Methyl hydrazine	6.78	Phenylenediamine	7.81
Cyanogen	6.79	Di-n-propylnitrosoamine	7.83
Ethylene oxide	6.86	Pyridine	7.83
N-Nitrosodiethylamine	6.86	Ethyleneimine	7.86
2-Chlorophenol	6.89	1,1-Dimethylhydrazine	7.87
N-Phenylthiourea	6.93	1,2-Dimethylhydrazine	7.87
Acrolein	6.95	N-Nitrosomethylvinylamine	7.91
2-Butenone peroxide	6.96	2-Acetylaminofluorine	7.92
p-Dimethylaminoazobenzene	6.97	Acrylonitrile	7.93
1,4-Naphthoquinone	6.97	Methapyrilene	7.93
3-(alpha-Acetonylbenzyl)-4-hydroxycoumarin and salts (Warfarin)	7.00	Strychnine and salts	8.03
N-Nitrosodiethanolamine	7.02	Methyl ethyl ketone (MEK)	8.07
N-Nitrosopiperidine	7.04	Cresylic acid	8.09
N-Nitrosonornicotine	7.07	Cresol	8.18
		Toluene diamine	8.24

Table I-11. (Part 2 - continued)

Hazardous Constituent	Heat of Combustion kcal/gram	Hazardous Constituent	Heat of Combustion kcal/gram
Acetophenone	8.26	Diphenylamine	9.09
Butyl benzyl phthalate	8.29	2-Methylaziridine	9.09
Ethyl cyanide	8.32	Benzidine	9.18
Bis (2-ethylhexyl) phthalate	8.42	Benzo (b) fluoranthene	9.25
Benzenethiol	8.43	Benzo (j) fluoranthene	9.25
N-Nitrosodi-N-butylamine	8.46	Benzo (a) pyrene	9.25
2,4-Dimethylphenol	8.51	Dibenzo (a,e) pyrene	9.33
Indenol (1,2,3-c,d) pyrene	8.52	Dibenzo (a, h) pyrene	9.33
Diethylstilbestrol	8.54	Debenzo (a,i) pyrene	9.33
1-Naphthylamine	8.54	Fluoranthene	9.35
2-Naphthylamine	8.54	Benz (a) anthracene	9.39
Methacrylonitrile	8.55	Dibenz (a,h) anthracene (Dibenzo (a,h) anthracene)	9.40
Isobutyl alcohol	8.62	Dibenz (a,h) acridine	9.53
1,2-Diethylhydrazine	8.68	Dibenz (a,j) acridine	9.53
2-Picoline	8.72	alpha, alpha-Dimethylphenethylamine	9.54
Aniline	8.73	3-Methylcholanthrene	9.57
1,2-Diphenylhydrazine	8.73	n-Propylamine	9.58
3,3'-Dimethoxybenzidine	8.81	7,12-Dimethylbenz (a) anthracene	9.61
7H-Dibenzo (c,g) carbazole	8.90	Naphthalene	9.62
Benz (c) acridine	8.92	Benzene	10.03
Nicotine and salts	8.92	Toluene	10.14
4-Amino biphenyl	9.00		

Source: Reprinted from USEPA and MITRE 1983.

Table I-12. Hazardous Waste Incineration Processes and Their Typical Operating Ranges

Process	Temperature range, °F (°C)	Residence time
Rotary kiln	1,500 to 2,900 (820 to 1,600)	Liquids and gases, seconds; solids, hours
Liquid injection	1,200 to 2,900 (650 to 1,600)	0.1 to 2 seconds
Fluidized bed	840 to 1,800 (450 to 980)	Liquids and gases, seconds; solids, longer
Multiple hearth	Drying zone 600 to 1,000 (320 to 540) Incineration 1,400 to 1,800 (760 to 980)	0.25 to 1.5 hours
Coincineration	300 to 2,900 (150 to 1,600)	Seconds to hours
Starved air combustion/pyrolysis	900 to 1,500 (480 to 820)	Tenth of a second to several hours

Source: Monsanto 1981.

Table I-13. Polycyclic Aromatic Hydrocarbon (PAH) Emissions from Municipal Solid Waste Incinerators in Micrograms per Kilogram of Refuse Charged

Compound[a]	0.52 kg refuse/s; Batch; Multiple Chamber (before scrubber)	0.52 kg refuse/s; Batch; Multiple Chamber (after scrubber)	2.6 kg refuse/s; Continuous; Multiple Chamber (no emission controls)
Benzo(a)pyrene	13	0.20	0.17
Pyrene	110	4.6	18
Benzo(e)pyrene	26	1.3	0.75
Coronene	33	1.4	0.53
Benzo(ghi)perylene	75	1.4	ND[b]
Fluoranthene	10	7.3	22
Phenanthrene	40	ND[b]	ND[b]
BSO[c]	6.8[c]	13[c]	40[c]

[a] Perylene, anthracene, and anthanthrene were not detected in any of the samples from these two incinerators.

[b] ND = Not Detected.

[c] Benzene soluble organics (BSO) is reported as mg BSO/kg refuse charged.

Source: USEPA 1980c.

Table I-14. Polycyclic Aromatic Hydrocarbon (PAH) Levels in Air Emissions, Solid Waste Residues, and Scrubber Water Discharge from a Municipal Solid Waste Incinerator[a]

Compound	Stack Gases & Particulates µg/kg refuse	Solid Waste Residue µg/kg refuse	Scrubber Water Discharge µg/kg refuse
Fluoranthene	2.5	12.4	0.14
Pyrene	6.8	10.5	0.12
Benzo(a)anthracene + chrysene	3.1	36.6	0.15
Benzo(b)fluoranthene + benzo(k)fluoranthene + benzo(j)fluoranthene	1.4	62.5	0.032
Benzo(a)pyrene + benzo(e)pyrene	0.09	31.5	0.032
Perylene	0.77	17.5	0.030
Benzo(ghi)perylene	1.8	10.0	0.007
Indeno(1,2,3-cd)pyrene	0.77	<2.1	<0.002
Coronene	0.2	<4.3	<0.002

[a] Incinerator rated at 2.5 kg/s, continuous feed, utilizing a wet scrubber followed by an electrostatic precipitator for particulate control. Other characteristics: rocking bar-type grate with burning rate 0.101 kg/s-m^2; primary air = 15-20% excess of theoretical, secondary air = 0-70% excess; stack gases = 10.9 m^3/s (dry) at 293 K, 1 atmosphere; residue = 0.7 kg/s at 23% average moisture content; scrubber water discharge = 0.58 liters/s (input water totalling approximately 0.28 µg/l of the indicated PAH compounds).

Source: USEPA 1980c.

APPENDIX J

AUXILIARY INFORMATION ON DEEP-WELL INJECTION

Table J-1. Compounds that have been Disposed of by Deep-well Injection

Chemical
Acetaldehyde
Acetic acid
Acetone
Acetylene
Acrolein
Adipic Adic
Adiponitrile
Allyl Alcohol
Aluminum Oxide
Amides
Ammonia
Ammonium Chloride
Ammonium Chromate
Ammonium Dichromate
Ammonium Hydroxide
Ammonium Nitrate
Ammonium Thiocyanante
Amyl Alcohol
Aniline
Arsenic Trioxide
Benzene
Benzoic Acid
Boron
Boron Chloride
Butane
Butanol
Butyl Disulfide
Butyl Mercaptan
Butyl Phenol
Butyric Acid
Cadmium
Cadmium Chloride
Calcium Chloride
Calcium Hydroxide
Calcium Oxide
Caprolactum
Carbon Disulfide
Chlorine
Chloroform
Chlorinated Hydrocarbons

Table J-1. (Continued)

Chemical
Chromic Acid
Copper Chloride
Cresol
Cumene
Cumene Hydroperoxide
Cyclohexane
Diazinon
Diethylstilbestrol
Dinitrobenzene
Dinitrotoluene
Dioxane
Diphemyl Amine
Epichlorohydrin
Ethane
Ethers
Ethyl Acetate
Ethyl Disulfide
Ethylene
Ethylene Glycol
Ethyl Mercaptan
Ethyl Phenol
Ferric Chloride
Ferrous Chloride
Ferrous Sulfate
Formaldehyde
Formic Acid
Glycerin
Gold Chloride
Hexamethylenediamine
Hexanol
Hydrochloric Acid
Hydrogen Cyanide
Hydrogen Peroxide
Magnesium Oxide
Mercury
Mercuric Chloride
Mercuric Diammonium Chloride
Mercuric Nitrate

Table J-1. (Continued)

Chemical
Mercuric Sulfate
Methane
Methyl Acetate
Methyl Cellulose
Methyl Ethyl Ketone
Methyl Mercaptan
Methyl Methacrylate
Nitric Acid
Nitrobenzene
p-Nitrophenol
Phenol
Phosphorous Oxychloride
Phosphorous Pentachloride
Phosphorous Trichloride
Polyvinyl Alcohol
Potassium Chromate
Potassium Dichromate
Potassium Sulfate
Propanol
Propargyl Alcohol
Propylene Oxide
Radium - 226
Silica
Silicon Tetrachloride
Silver Chloride
Sodium Carbonate
Sodium Chromate
Sodium Dichromate
Sodium Ferrocyanide
Sodium Fluoride
Sodium Formate
Sodium Hypochlorite
Sodium Monoxide
Sodium Nitrate
Sodium Nitrite
Sodium Sulfate
Sodium Sulfite
Stannic Oxide

Table J-1. (Continued)

Chemical
Sulfuric Acid
Terephthalic Acid
Thorium - 230
Toluene Diamine
p-Toluic Acid
Uranium
Urea
Valeric Acid
Vanadium Pentoxide
Vinyl Acetate
Xylene
Xylenol
Zinc Oxide

Source: Reeder et al. 1977a.

Table J-2. Modified Theis Equation

$$r = \left(\frac{2.25\ K\ H\ t}{S \cdot 10^{X}} \right)^{1/2}$$

where:

$$X = \frac{4 \pi KH \left(h_w - h_{b_o} \times SpG_b \right)}{2.3\ Q}$$

r = Radius of endangering influence from injection well (length)

K = Hydraulic conductivity of the injection zone (length/time)

H = Thickness of the injection zone (length)

t = Time of injection (time)

S = Storage coefficient (dimensionless)

Q = Injection rate (volume/time)

h_{b_o} = Observed original hydrostatic head of injection zone (length) measured from the base of the lowest underground source of drinking water

h_w = Hydrostatic head of underground source of drinking water (length) measured from the base of the lowest underground source of drinking water

SpG_b = Specific gravity of fluid in the injection zone (dimensionless)

π = 3.142 (dimensionless).

Source: USEPA 1981d.

Table J-3. Information on the Survey Waste Injection Program (SWIP)

USE: The SWIP model is applicable for modeling the transport of momentum, energy and contaminant mass in porous media due to deep well injection or other sources.

DEVELOPED BY: INTERCOMP Resource Development and Engineering, Inc. and INTERA, Inc.

DEVELOPED FOR: U.S. Geological Survey, Water Resources Division

REFERENCE: INTERCOMP, Inc., 1976, A Model for Calculating Effects of Liquid Waste Disposal in Deep Saline Aquifer, Part I and II, U.S. Geological Survey, Water-Resources Investigations 76-61, June, 1976.

INTERA, Inc., 1979, Revision of the Documentation for a Model for Calculating Effects of Liquid Waste Disposal in Deep Saline Aquifers, U.S. Geological Survey, Water-Resources Investigations 79-96, July 1979, 73 p.

ASSUMPTIONS:

- Fluid flow in the aquifer can be described by Darcy's law for flow through a porous medium.
- Fluid density can be a function of pressure, temperature and contaminant concentration. Fluid viscosity can be a function of temperature and concentration.
- The waste or contaminating fluid is totally miscible with the in-place fluid.
- Hydrodynamic dispersion is described as a function of fluid velocity.
- The energy equation can be described as "enthalpy in - enthalpy out = change in internal energy of the system." This is rigorous except for kinetic and potential energy which have been neglected.
- Water table conditions in an unconfined aquifer can be approximated by no capillarity and no residual water saturation (specific retention).
- Contaminant reaction can be described by a first order reaction - similar to radioactive decay.
- Contaminant adsorption on rock surfaces can be described by linear adsorption isotherms.
- Aquifer properties vary with position-porosity, permeability, thickness, depth, specific heat and adsorption distribution coefficient.
- Boundary conditions allow natural water movement in the aquifer, vertical recharge in the uppermost layer; heat losses to the adjacent formations, and the location of injection, withdrawals and observation wells anywhere within the aquifer system.

Table J-3. (Continued)

APPROXIMATING METHOD:
- Finite-difference

SOLUTION TECHNIQUES:
- Reduced bandwidth direct
- L2SOR

GEOMETRY:
- 1-, 2-, or 3-dimensional Cartesian
- Cylindrical

OPTIONS:
- Steady or transient flow
- Solute transport
- Heat transport
- Wellbore
- Heterogeneous and/or anisotropic media
- Confined and/or water-table conditions
- Recharge and/or wells

BOUNDARY CONDITIONS:
- Specified value
- Specified flux
- Aquifer influence function

Source: Mercer et al. 1981.

APPENDIX K

USEFUL CONVERSION FACTORS

Table K-1. Useful Conversion Factors

ton, short	x	0.907	=	metric ton (kkg)
inch (in)	x	2.54	=	centimeter (cm)
centimeter	x	0.3937	=	inch
feet (ft)	x	0.3048	=	meter (m)
meter	x	3.2808	=	feet
mile (mi)	x	1.609	=	kilometer (km)
kilometer	x	0.621	=	mile
U.S. gallon (gal)	x	0.0038	=	cubic meter (m^3)
cubic meter	x	264.17	=	U.S. gallon
cubic feet (ft^3)	x	0.0283	=	cubic meter
cubic meter	x	35.314	=	cubic feet
acre-foot (ac-ft)	x	123.53	=	cubic met
cubic meter	x	0.0008	=	acre-feet
hectare	x	10,000.0	=	square meter
square meter	x	0.0001	=	hectare
hectare	x	2.471	=	acre
acre	x	0.4047	=	hectare

Hydraulic Conductivity

gpd/ft^2	x	4.72×10^{-5}	=	cm/sec
cm/sec	x	21.2×10^{3}	=	gpd/ft^2
Darcy	x	18.2	=	gpd/ft^2
Darcy	x	8.58×10^{-4}	=	cm/sec

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15. Supplementary Notes

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16. Abstract (Limit: 200 words)

This report, which is part of a series of volumes on exposure assessment, presents methods for estimating environmental releases of chemical substances from disposal sites. These release estimates must be used in conjunction with procedures given in Volume 2 (ambient exposure category) and Volume 5 (drinking water exposure category) in order to complete the exposure assessment. A five-stage methodological framework outlines the major steps that must be taken in order to estimate releases from disposal by landfilling, land treatment, surface impoundment, municipal wastewater treatment, incineration, and deep-well injection. The methods are applicable to chemical substances in all of the following waste categories: municipal solid waste, industrial solid waste (hazardous and nonhazardous), municipal wastewater, wastewater treatment sludges, and incinerator residues. The report provides guidance on information resources useful in completing each step and also discusses data gaps and limitations in predictive capability. Sample data and summaries of information resources are included in appendices.

17. Document Analysis a. Descriptors

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